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ELECTROTHERAPEUTICS

VON ZIEMSSEN'S

HANDBOOK

OF

GENERAL THERAPEUTICS

IN SEVEN VOLUMES—VOL. VI.

ELECTROTHERAPEUTICS

BY

WILHELM ERB, M.D.

LONDON
SMITH, ELDER, & CO., 15 WATERLOO PLACE
1887

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ELECTROTHERAPEUTICS

BY

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PROFESSOR OF CLINICAL MEDICINE AT HEIDELBERG

TRANSLATED BY

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With Thirty-nine Illustrations

LONDON
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TRANSLATOR'S PREFACE.

I TRUST the reader will forgive the use in this translation of a few words not to be found in the dictionary. Technical terms in the original German, such as 'labile' and 'stabile,' had either to be adopted as they stood or to be rendered by a circumlocution. I have chosen the former alternative.

I regret that Professor Erb, whilst approving of the term 'subaural galvanisation,' proposed by myself as a substitute for the objectionable phrase 'galvanisation of the sympathetic,' did not adopt it throughout the original edition; but here, as throughout the volume, my aim has been to present to the reader the Author's meaning as much as possible in his own language.

My best thanks are due to my coadjutors in the work of translation. To my friend Dr. Cagney, Assistant-Physician in the Electrical Department of St. Mary's Hospital, I am especially grateful for the intelligent zeal with which he also revised the proofs and indexed the volume.

A. DE WATTEVILLE.

WELBECK STREET: *April* 1887

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LECTURE I.

Historical Survey—Beginnings of Electrotherapeutics—Electrical Machine—Static Electricity—Galvani's Discovery—Dynamic Electricity—First Period: Galvanotherapeutics—Induction—Second Period: Faradisation—Duchenne—Froriep—Third Period: Reintroduction of Galvanisation—Remak—Brenner—Recent Electrotherapeutics—Its Aims and Development.

Gentlemen,—The vast extent and continuous growth of medical science make division of labour in the field of research absolutely necessary. The tendency to specialisation has become irresistible; it is a logical consequence of the conditions under which we have to work. The most capacious intellect can no longer cover the whole province of knowledge or embrace all its details, far less master them. Hence by a natural process the larger departments of medicine, surgery, and obstetrics have already for a long time been recognised as independent and homogeneous wholes. Gynæcology, ophthalmology, dermatology, otology, neurology are at the present time going through a similar process of abstraction.

Even in therapeutics a certain amount of specialisation is becoming necessary. The adoption of certain processes of treatment, requiring previous preparation and training in outlying branches of knowledge, the use of complicated apparatus, and much personal practice in the details of the methods, has given rise to this necessity. It is not medicine which has suffered from the process, but rather the specialists themselves, who become exposed to the dangers of exclusiveness and its unfortunate consequences.

From the subdivision of therapeutics result hydrotherapy, orthopædics, massage, gymnastics, balneotherapy, aerotherapy, and more especially *electrotherapy*, by which term is understood the treatment of disease by means of electrical currents. The electrical current with its various modifications, gentlemen, is the one therapeutic agent which we shall consider in these lectures. Electricity, which plays such an important part in modern diagnosis and therapeutics, has been the subject of so many investigations in its relation to animal tissues, has proved in so many different cases a powerful and unique means of cure, that it is the duty of every physician worthy of the name to devote some attention to this agent and its uses in the practice of medicine.

You all know of the striking developments which neuropathology has undergone during the past few years. It is not our task here to trace the causes of its progress, but we may affirm that electrotherapy is intimately bound up with it. Whilst on the one hand neuropathology has been enriched by substantial contributions at the hands of electrotherapeutists, on the other the increase in depth and breadth of our neurological knowledge has reacted most beneficially upon the application of electricity to medical purposes.

The use of electricity as a means of testing the excitable tissues rests upon a basis of significant physiological data, and constitutes an important, often indispensable, means of diagnosis in a number of nervous diseases. In not a few cases too electrical examination enables us to establish a prognosis of surprising exactitude. Finally, the apparently increasing number of the nervous ailments attendant upon modern life encourages the extensive application of a means of treatment which has already for a long time occupied an important position and rivals all others in the diversity, energy, and certainty of its effects.

The necessity of being conversant with the behaviour of electricity, and its effects on the body in health and disease, has thus become absolute for every neuropathologist; it is one of the main subjects which he must study. And where is the physician nowadays who must not be something of a neuropathologist? Do not 'neuroses' form a most important department in one's everyday practice? Nobody, therefore, will find the possession of electrotherapeutical knowledge useless. We are far from pretending that every physician should be a thorough master of electrical diagnosis and treatment, nor do we wish to add unduly to the weight of his already overburdened shoulders; but we content ourselves with the reasonable demand that he should possess an elementary knowledge of the subject and that he should be conversant with the most important indications for electrical treatment in the commoner forms of disease. Thus only will he be able to do for his patients the proper thing at the proper time.

Allow me at the outset to throw a retrospective look upon the development of electrotherapeutics in former times.

Antiquity does not furnish us with many data. As long as men were unable to generate electricity in sufficient quantities, anything like a regular medicinal application of it was out of the question. Still we hear that the sources of electricity supplied directly by nature were turned to therapeutical uses. It is said that patients suffering from gout, paralysis, and other disorders were placed by Roman physicians in baths containing electric fishes, whose discharges were thought to be beneficial.

The invention of the electrical friction machine facilitated the use of this agent; yet, though largely employed, we do not see that the results amounted to much. De Haën, Kratzenstein, Krüger, in Germany; Jallabert, Sigaud de la Fond, Bertholon, Mauduyt, in France, are among those who, in the last century, applied the electrical machine to therapeutics. Mauduyt in 1773 and 1778 reported many facts of high promise. But it was only after Galvani's celebrated discovery (1786) that electrotherapeutics received a great and durable impulse. A new epoch was entered upon, of which the initial period extended over the first twenty or thirty years of this century. The invention of the voltaic pile in 1800 gave to Galvani's discovery its true value and laid the foundation of its applicability to practical ends.

Alex. von Humboldt had previously (1797) published his well-known book on 'The Excited Nervous and Muscular Fibres,' and thus entered upon the road, since then followed with so great results, of electrophysiological enquiry.

The most distinguished physicians of the time—Hufeland, Reil, Sömmering, Pfaff, and others—directed their attention to the newly-discovered force; and there soon appeared books by German physicians (Grapengiesser, Augustin, Loder, Bischoff, Jacobi, Walther, &c.) treating of the curative value of galvanism, and praising its influence in a number of nervous and other disorders (asphyxia, paralysis, nervousness, weakness of sight and cataract, deficient hearing, aphonia, rheumatism, toothache, &c.) Numerous experiments with galvanism were being at the same time made in France and Italy.

The development of electrotherapy came, however, to a standstill; it fell into decadence, owing chiefly to the expense and trouble entailed by the possession of instruments and to a deficient pathological knowledge. A host of quacks occupied the ground, and electricity, mixed up with animal magnetism and mesmerism, lost its credit.

Most, in 1823, made a futile attempt to save the honour of galvanism and reintroduce it into therapeutics.

A new era soon after began in connection with the discovery by Oersted (1820) of the magneto-electric phenomena, and that by Faraday (1831) of the phenomena of induction. This era may be characterised as the epoch of the induced current, of faradisation.

During the fourth decade of this century instruments were contrived giving magneto-electric and volta-electric induction currents. These machines yielded, at all times and with comparative ease, currents of great physiological energy; they required but a small expenditure of time and labour to be kept in action; and improvements were soon made (automatic interrupter, &c.) which adapted them peculiarly to the requirements of medical practice. The ease with which muscular contractions were obtained by their means, and the belief which then existed in the similarity of action of all electrical currents, naturally made these apparatus very popular among physicians. The familiar buzz, heard on all sides, testified to the vigour of the new electrotherapeutic movement, with which one name is intimately associated—casting into the shade those of Marshall Hall and Golding Bird, as well as that of Froriep, who largely applied in Germany the magneto-electric current—the name of Duchenne (de Boulogne), who in France carried out his remarkable investigations with the volta-electric induction apparatus.

To this great man we owe some of the most important advances of the time. Duchenne may rightly be considered as the founder of modern electrotherapeutics, though his greatest achievements do not actually lie in that direction. It is his electrophysiological researches, and still more his neuropathological discoveries, which constitute his true claim to glory. He was an observer of extraordinary acuteness, of matchless care and accuracy in his description of morbid types. Look, for instance, at his accounts of locomotor ataxy, of bulbar paralysis, of progressive muscular atrophy, of infantile paralysis, of partial paralyses of single muscles or muscular groups.

The use of the faradic current—faradisation, as he himself called it later—did him eminent service in his researches. He started from the fact that the faradic current may be, through appropriate methods of application, 'localised' in parts lying at a certain depth under the skin. Upon this basis he founded his system of 'faradisation localisée,' by means of which he carried out his investigations of the muscular system in health and disease. As a consequence of his views and methods, the principle was established that electric currents must be localised in the individual diseased parts in order to obtain curative results.

From 1847 to 1850 he published several papers wherein he describes his method (named by him at first 'galvanisation localisée'), as well as his physiological investigations concerning the functions of various muscles. The latter he eventually expanded into a complete 'Physiologie des Mouvements' (1857), wherein he records exact results as to the action of all the muscles which can be investigated by his method, and establishes numerous conclusions applicable to pathology. A valuable series of electrodiagnostic observations came next, especially concerning peripheral traumatic paralyses, infantile paralysis, progressive muscular atrophy, partial muscular paralyses, &c. These, with his therapeutical contributions, were collected in his great work 'De l'Electrisation Localisée,' the first edition of which appeared in 1855. In the course of time he extended his therapeutical enquiries into other subjects, such as facial paralysis, neuralgia, anæsthesia, surdo-mutism, &c. On the other hand, Duchenne did not conceal his conviction that the faradic current was of no great avail in diseases of the central nervous system.

Duchenne's labours, vitiated as they were to some extent by physical errors and therapeutical illusions, were received very warmly by the medical profession, not only in France but also in

Germany. A German edition of his book was prepared by Erdmann; M. Meyer, Baierlacher, Althaus, Schulz and others were stimulated by his influence, and brought out in quick succession a number of excellent contributions.

The method of Duchenne, though empirical in its origin, was generally accepted, and everywhere found adepts, owing to its simplicity and practicability. Duchenne had found that muscles could be excited directly as well as indirectly (that is, from the nerves), and that this could be best effected at one or more points of their surface. He called such points 'points d'élection.' R. Remak showed that these points were nothing but the points of entrance of the motor nerves into the muscles, and that, as a rule, it is better to excite the muscles through their motor nerves than to do it directly. Thereupon arose a controversy, not very edifying in itself, but which nevertheless contributed not a little towards clearing up the subject and establishing the principles of 'localised faradisation.' Ziemssen followed up Remak's idea, and carefully investigated the 'motor points' both on the living and the dead body. He confirmed the statement that they represented points where the motor nerves (within, or on the edge of, muscles) were situated sufficiently near the skin to be reached by the faradic current. The results of his researches were published in his valuable work 'Electricity in Medicine,' the later editions of which contributed greatly to the progress of electrotherapeutics.

Duchenne's method thus became, through the zealous efforts of numerous investigators, the common possession of physicians, who applied it to the treatment of muscular and paralytic affections, as well as to some neuralgic and spasmodic diseases.

From about this same period (1850) date the beginnings of a new electrophysiological era; it was then that the first enquiries into the electrical phenomena of living nerve and muscle, and into the effects of currents upon these structures, were published. The names of du Bois Reymond, Eckhard, Pflüger are sufficient to remind you of the facts of nerve and muscle current, electrotonus, the law of contractions, &c.

A fact discovered by Eckhard, and which was ascribed by him to the 'paralysing' influence of the galvanic current upon nerve and muscle, induced R. Remak to apply this current to the human subject (Dec. 1855). A large number of preliminary physiological experiments led him to make, on June 22, 1856, his first therapeutical experiment: it was the resolution of a contracture. Its result was surprising, and further attempts in the same and other directions were also successful. Thus the first step was made towards the restoration of the galvanic current as a means of treatment, and with it the present epoch of electrotherapeutics was entered upon.

With restless energy Remak continued his experiments upon a vast number of patients, and with him will always remain the credit of having established the therapeutical application of the galvanic current upon a broad and imperishable basis. The first complete *exposé* of his results appeared in 1858 under the title 'Galvanotherapie der Nerven- und Muskelkrankheiten.' The book contains full historical notices, accounts of his physiological and therapeutical experiments, and more especially a description of what he calls the 'catalytical' effects of the current. The action of electricity in inflammatory and similar processes he thought to be its most promising feature. Its 'antiparalytic' and 'antispastic' virtues he leaves somewhat in the shade.

This work, the result of innumerable and painstaking observations, is rich in interesting facts and details ; but, though opening up a wide horizon for the usefulness of the galvanic current, it was looked upon with a strange reserve by the medical profession. The considerable reputation acquired by its author through important researches in other fields of medical knowledge did not protect him from a cold reception here ; his results in the field of electrotherapeutics were held in but very low esteem. It is true that several circumstances stood in his way, such as the somewhat excessive enthusiasm into which he was betrayed by his brilliant results, the apparent unlikelihood of some of his statements, the boldness of his physiological explanations and of his diagnostic and therapeutic hypotheses.

Remak continued to devote himself zealously to the study of galvanotherapeutics, but it is to be regretted that he published nothing further except a few short papers and communications. In 1864 he gave lectures in Paris, which appeared in the French language; they contain in a fragmentary form the most important views, as well as the germs of many new facts and ideas. Remak was prematurely taken away from science in 1865. It was not granted to him to enjoy the full recognition of his work, though during the last few years he witnessed some of his results confirmed by other observers, and saw the prejudices which had opposed him gradually melting away. Nor was this a rapid process. At first there were but few electrotherapeutists (Baierlacher, M. Meyer, Erdmann, Schulz) who displayed a sort of mistrustful interest in Remak's work, and made some experiments of their own in the same direction. Benedikt, of Vienna, starting from Remak's position, occupied himself more extensively with the applications of the galvanic current; his first papers appeared in 1861–62. Later he collected his materials into a larger work, 'Elektrotherapie' (1868), much of which, however, is devoted to neuropathology. The book attracted many readers by its richness in interesting facts, its novel views and ingenious hypotheses; but the numerous errors and contradictions, the premature statements and other shortcomings in which it abounded exposed it to very severe and not undeserved criticisms. Still it was not without a certain influence upon the development of electrotherapeutics.

At the same time a physician of St. Petersburg, named Brenner, was investigating the therapeutical applications of the galvanic current in a thoroughly independent and original manner. His publications are distinguished by the accuracy and fidelity of their observations, the precision of the conclusions reached, and the importance of their results as bearing upon medical practice. In 1862 Brenner published a paper in which he defined the 'polar' method of investigation and treatment, and opposed it to the 'directional' method of Remak, Benedikt, and others. The polar method proved to be based upon sound physical and physiological principles, and its promulgation was the signal of fresh progress in electrotherapeutics. The physiological basis of the method had, it is true, been already laid down in the writings of Baierlacher and Chauveau. The former had even applied the method of unipolar stimulation to the human subject, and characterised it with the utmost clearness; but Brenner was the first to recognise its necessity for diagnostic and therapeutical purposes. In 1868–69 appeared his larger work, containing the result of his masterly and successful labours in this field, a work which ranks among the most valuable contributions to our literature and is a model as a record of accurate observations and an instance of the scientific application of facts.

What has contributed most to the repute, and even to the over-estimation of the galvanic current, was perhaps the phenomena observed in certain peripheral paralyses. We mean the facts of the 'reaction of degeneration,' with which you will become acquainted later on, and which attracted universal attention when first described by Baierlacher (1859), Schulz, Brenner, Von Grünewaldt, Neumann, M. Meyer, and others. The progress made upon this subject, and the recognition of the galvanic current by Ziemssen in the third edition of his work, wakened general interest and stimulated the efforts of numerous observers in the direction of experiment and therapeutics.

And so, since the year 1865 to the present time, a number of zealous disciples have arisen who have laboured to strengthen and add to the structural edifice of electrotherapeutics. My own connection with the subject began in 1865. Hitzig, Eulenburg, Seeligmüller, Burckhardt, Filehne, Berger, Bernhardt, E. Remak, Fischer, belong to the same period. From 1867 to 1876 there appeared a large number of volumes of more or less considerable size, some new, some expanded editions of former works (Meyer, Benedikt, Erdmann, Rosenthal, &c.); as well as of various papers (Erb, Seeligmüller, Bärwinkel, &c.), and special enquiries tending to widen the domain of electrotherapeutics in every direction. I can only mention the latter, arranging them in appropriate groups.

We must first take the preparatory physical contributions, which threw light upon the possibility of reaching various parts of the body, especially the brain and the cord, which was then doubted (Erb, 1867; Burckhardt, 1870; Ziemssen, 1872; Charcot, 1882). Next appeared contributions giving valuable information as to the direction and diffusion of derived currents in the body, with varying positions of the electrodes (Helmholtz and Erb, 1867; Burckhardt, 1870; Filehne, 1870; Ziemssen, 1872); whilst others threw light upon the resistance of the human body and its modifications (Vigouroux, 1881; Estorc, 1882; Gärtner, 1882; Jolly, 1884). Under the same heading we may mention the introduction of appropriate apparatus and accessories into the electrotherapeutical technique (commutator, rheostat, galvanometer); the improvement of batteries, especially of a portable and yet effective description. Considerable progress had been made since the time when Remak was obliged to take to pieces and clean daily his batteries of Daniell's elements.

Physiological experiments on the living man were pursued with much zeal, with a view to confirming the results obtained in animals and establishing their value from a diagnostic and pathological point of view. The law of contractions especially was investigated in connection with several nerves of the human body, and the results were found to agree in the main with Pflüger's law (Baierlacher, 1859; Brenner, 1862 and 1869; Ziemssen, 1866 and 1872; Erb, 1867; Benedikt, 1870; Filehne, 1870; Burckhardt, 1875; Rumpf, 1878).

The phenomena of electrotonus were likewise closely studied, and, after many difficulties, found to correspond in the living man with the data of physiologists (Eulenburg, 1867; Erb, 1867; Samt, 1868; Brückner, 1868; Runge, 1870; E. Remak, 1876; Waller and de Watteville, 1882).

The cervical sympathetic was the subject of predilection with many experimenters, who attributed a great curative virtue to its galvanisation, but whose physiological explanations were very unhappy (Gerhardt, 1864; Benedikt, 1867; Eulenburg and Schmidt, 1868; Meyer, 1868, 1870; Flies, 1868; Beard and Rockwell, 1870; Otto, 1873; G. Fischer, 1875–77).

The effects of the galvanic current on the organs of sense were also studied, and not without important practical results. Thus the galvanic reactions of the retina and optic nerve were investigated by Brenner (1868), who started from the results of Ritter, Purkinje, Helmholtz, &c. Brenner also in his great work treated exhaustively of the galvanic reactions of the acoustic nerve (Brenner, 1868; Hagen, 1869; Eulenburg, 1869; Erb, 1869–71; Neftel, 1871, &c.)

We may also mention the experiments with the galvanic current on the brain (Brenner, 1868; Hitzig, 1870, and others) and those on the production of heat in muscle (Ziemssen, 1856;

Althaus, 1868), not to speak of various other smaller contributions. The appropriate methods of investigation of physiological and pathological excitability were at the same time undergoing development. The polar method became the subject of much discussion (Brenner, 1862–69 ; Erb, 1867, 1872 ; Filehne, 1870 ; Burckhardt, 1870 ; Hitzig, 1873), and a better method for the quantitative estimation of excitability was elaborated (Erb, 1873 ; E. Remak, 1876).

The pathological changes of excitability were more exactly and thoroughly examined, and electrodiagnosis thereby placed on a firmer footing. The theoretical importance and practical bearing of the phenomena included under the name of 'reaction of degeneration' are now universally recognised. Though certain facts connected with it had been previously observed in some forms of paralysis (Baierlacher, 1859; Schulz, 1860; Brenner, Grünewaldt, 1862 ; Neumann, 1864; Eulenburg, Ziemssen, 1866 ; Erb, 1867, &c.), the reaction of degeneration was first made the subject of experimental researches by myself (1867–68) ; and the results so obtained were important. Ziemssen and Weiss almost contemporaneously (1868) confirmed these conclusions, which have since proved to be of the highest import for diagnosis and prognosis (Brenner, 1868 ; Eulenburg, 1867, 1868 ; Erb, 1874, 1876, 1878 ; Bernhardt, 1874, 1879 ; E. Remak, 1875, 1879 ; Goldschmidt, 1877 ; Leegaard, 1880 ; and many others).

Methods for testing the sensibility of the skin have been described by Leyden, Bernhardt, Erb and Drosdoff, Tschiriew and de Watteville, Möbius, whilst Brenner (1868) established the pathological changes in the acoustic reactions in all their theoretical and practical bearings. Later observers have been able only to confirm his results (Hagen, 1869 ; Erb, 1868–71 ; Eulenburg, 1872 ; Hedinger, 1870, &c.)

As was to be expected the curative effects of the current were not neglected during the same period of electrotherapeutical activity. The first task was to find out how far the expectations raised by Remak's writings were borne out by experience. New conquests could scarcely be expected ; the necessity was rather to impose a limit and subject Remak's assertions to a severe control. Innumerable facts have been collected ; the current has proved useful in many forms of nervous, muscular, and articular affections. Even in psychiatry it has made some way in the hands of Benedikt, 1870; Arndt, 1870–77; Tigges, 1873 and 1883.

It is unfortunate that no theory concerning the therapeutical influence of the current can be entertained as yet. All efforts and discussions to that effect have hitherto failed to yield satisfactory results (Remak, 1858; Brenner, 1862–69; Benedikt, 1867–74; Erb, 1872; Holst, 1872; Hitzig, 1873; C. W. Müller, 1885). All attempts to reduce the action of the current to the still obscure physiological effects (exciting and modifying influences, electrotonus, electrolysis, &c.) have ended in failures. Nor has the once general tendency to give the vasomotor changes (e.g. through 'galvanisation of the sympathetic') an important place among its effects promoted in any way scientific knowledge.

We are always brought back to the so called 'catalytical' effects of Remak, which shall be considered more fully later on, though we cannot be said to possess a clear conception of what is included under this term. Thus to the present time we are still in the empirical stage with regard to electrotherapeutics proper. Guided by physiological knowledge and past experience, we are competent to collect facts by means of scientific methods; but in their interpretation we must proceed with the utmost caution.

Whilst in Germany the greatest activity prevailed, electrotherapeutics was not cultivated with much vigour abroad. In France great obstacles stood in the way of the galvanic current, owing to the influence of Duchenne, who remained until the end faithful to faradism; even now it cannot be said to be thoroughly understood and accepted by the majority of the profession. After the work of Tripier (1861) came that of Legros and Onimus (1872), which has merits, though the standpoint taken by the authors with reference to physiological and pathological investigations does not appear to us quite correct. More recently a volume by Teissier (1878) has appeared, which is calculated to give to the French reader an idea of the results reached in Germany by scientific electrotherapeutical investigators; and Estorc's work on diagnosis rests upon the same basis. Static electricity has, under the auspices of Charcot, once more awakened the interest of numerous observers both in France and elsewhere (Vigouroux, Stein, Erlenmeyer, Möbius, Holst, Beard, and others).

In England still a longer time elapsed before a general interest was taken in the subject, and even now there are but few special labourers in the field. Althaus's book (1859–70) was for a long time the only one worth mentioning. More lately contributions have appeared by Russell Reynolds and Vivian Poore and others, as well as an excellent little book by de Watteville, the second edition of which contains a very clear exposition of electrophysics and electrodiagnosis. A volume by Hughes Bennett, which treats of the latter subject, deserves mentioning, as well as the excellent electrophysiological labours of Waller and de Watteville.

In America a greater activity has prevailed, and a fair number of physicians have taken up medical electricity. Several useful papers have been published by Neftel; Beard and Rockwell (1871) have written a large manual, containing much practical and original matter, among which we may mention the method of ‘general faradisation’ and ‘central galvanisation.’

In Italy, where the French influence prevailed, the faradic current has been extensively used, though the rather voluminous Italian literature has not been put much in requisition by foreign writers. Lately, however, the galvanic current has been brought to the front (Namias, Fubini, Pl. Schivardi, Ottoni, Rodolfi, Ciniselli, Brunelli, Vizioli, &c.) in that country.

It is evident from this survey that the new electrotherapeutics, which has already grown to be a considerable branch of medical knowledge, has been promoted mainly by German work and perseverance. May an increasing number of energetic young workers devote themselves to this field of labour, for there still stands an ample harvest to be gathered therein.

SECOND SECTION.

PHYSICAL INTRODUCTION.

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LECTURE II.

The Different Kinds of Current—Contact or Chemical Electricity—Galvanic Current and Cell—Induction Electricity—Faradic Currents—Usual Apparatus and Accessories—Coils and Batteries.

GENTLEMEN,—I am sure I may take it for granted that you are familiar with the physical theory of electricity in all its chief points. Such a knowledge forms the only reliable basis for a rational and successful application of the current to therapeutics and diagnostics. I cannot, therefore, too strongly urge you to spare no efforts in gaining a thorough mastery of the principles of electrical science, so far at least as they are involved in our special branch of the subject. You cannot become competent electrotherapeutists until you have done so; and you will find your work materially facilitated by a mastery of the short and excellent works of J. Rosenthal, Fick, Zech, v. Beetz, and de Watteville.

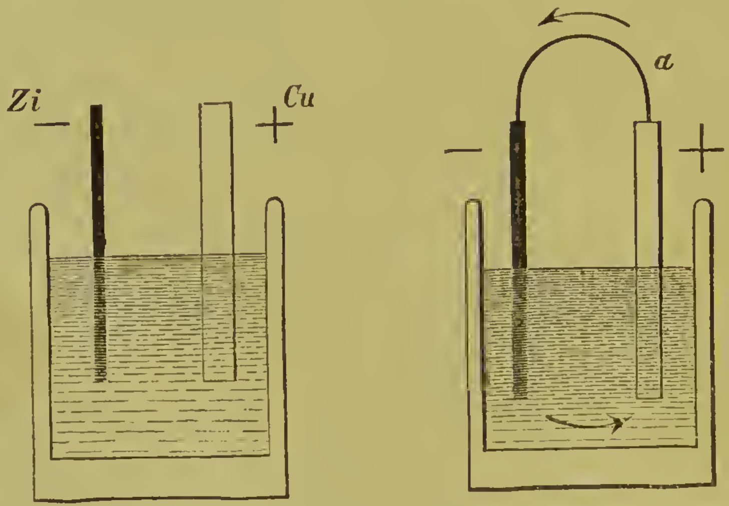
I cannot, however, avoid giving you a short account of the facts involved in what is to follow; but it will be a mere sketch which you will have to fill in for yourselves.

Electricity appears to be differently modified according to its mode of generation and the arrangement of the apparatus used for its production. For therapeutical purposes we employ dynamic electricity or the electrical current almost exclusively.

Many attempts have been made, and at various periods, to utilise frictional or static electricity in therapeutics; but they have—even those most recently made in Paris—not had such results as to secure for static electricity a certain position in this connection. We need not, therefore, speak of this form of electricity, which, moreover, obeys the same fundamental laws which govern the other form.

Electrical currents may be generated by various contrivances. For our purpose we use chiefly those originating in (1) the contact of two metals and the chemical action between them (galvanic, constant, or battery currents), (2) in the induction between two wires (faradic, interrupted, or induced currents). Currents produced by the powerful dynamo-electric machines used in electric lighting and the like need not be mentioned here, though they may eventually become adapted to the requirements of electrotherapeutics.

Galvanism.—The simplest construction for the generation of a 'constant' current (we need not here allude to the controverted points concerning the theory of galvanic electricity) is as follows: If you place two different metals (copper and zinc, or also carbon and a metal, such as zinc) in the shape of two parallel rods or plates in a liquid (a salt solution or dilute acid), the contact of these metals with the liquid produces a division of the electricity in the metals (fig. 1), in such a way



FIGS. 1 and 2.—Diagram of a galvanic cell. In fig. 1 the circuit is broken; in fig. 2 it is closed. *Zi*, zinc rod; *Cu*, copper or carbon plate. Both dip in dilute acid or a salt solution. + is the sign of the positive pole, or anode; −, of the negative pole, or kathode.

that all the positive electricity accumulates in one of the metals, all the negative in the other, with a certain difference of potential (so called 'tension'). This difference varies according to the metals and liquid used. Hence metals may be arranged in such an order as to form a series in which the metal standing at one end is most positive when in contact with a given liquid, and the one standing at the other end is most negative under the same circumstances.

The simple combination of two metals in a liquid is called an *open cell or circuit.* If you connect the free ends of the metals together by means of a conductor, such as a metallic wire, so as to effect a closure of the circuit (comprising the liquid, the metals, and the wire), the difference of potential between the two metals tends to become equalised. The electricity flows from the one to the other; we have a *closed cell or circuit,* in which a current moves.

This equalisation does not, however, become absolute with the closure of the circuit; for there occurs a persistent redistribution of electricity, owing to the chemical action that occurs at the point of contact of the metals with the liquid. Tension is ever renewed as long as there is metal and liquid left, which gives rise to a continuous flow of electricity in the circuit.

The property of keeping up a certain difference of potential is called the *electromotive force* of the galvanic couple. Its degree depends solely upon the quality of the metals and liquid used. The greater the difference of potential between the two metals, the greater the quantity of electricity set free, and, *cæteris paribus*, the stronger the current generated.

If you connect together several such simple cells or elements so that one metal of the one be attached to the other metal of the other (fig. 3) the tensions existing in each are added, and the sum total of all act at the two ends of such a battery. The current passing through the wire connecting the two extremities, positive and negative respectively, of the battery is correspondingly stronger. This method of connecting the single cells together is called 'arrangement in series.' In electrotherapeutics we always use this arrangement for all applications to the surface of the body (our reasons for doing so will be given further on); the elements, connected in series, are made into batteries of variable numbers according to our needs. In what follows it will always be implied that the cells are arranged in such series.

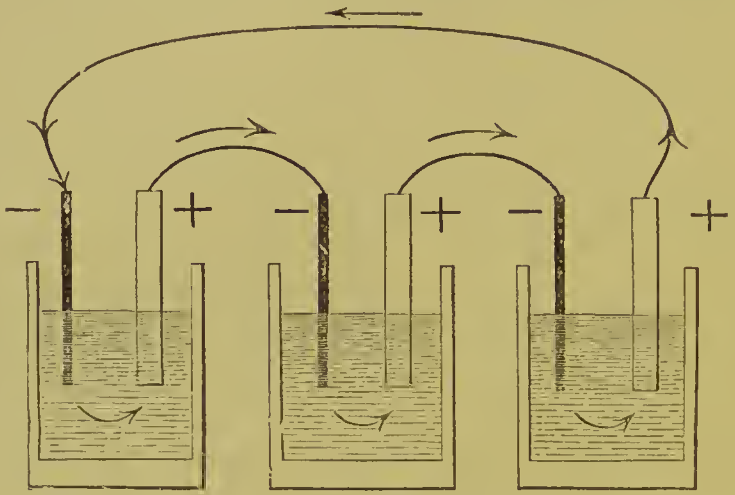


FIG. 3.—Three cells connected in series to form a battery. The arrows show the direction of the current.

The external part of the circuit of a battery is formed by the conductor connecting the first and last cell. The current which flows through it has a definite strength and direction, and naturally travels within the battery in a direction opposed to that it has externally—namely, from zinc to carbon inside the cells, from carbon to zinc outside. The end of the battery from which the current emerges to enter the external conductor is called *positive pole*, or *anode*; the other end at which it enters the battery again, *negative pole*, or *kathode.*

Let us now divide the wire which we may suppose to be connecting the two poles of the battery and fix its free extremities to any conducting body (*a*, fig. 4). The current will pass through this body also, according to the laws which govern its manifestations. This is what happens when the body, or a part of it, is intercalated into the circuit. The point of entrance and exit of the current, and its diffusion in the body, depend upon the points where we apply the two extremities of the wire, the resistance of the body, &c. All these conditions are subjected to laws of which we shall presently speak. We also call positive pole, or anode, the portion of the external circuit which brings the current to the body, and negative pole, or kathode, the portion through which it leaves the body. The actual instruments which are used to effect contact between the body

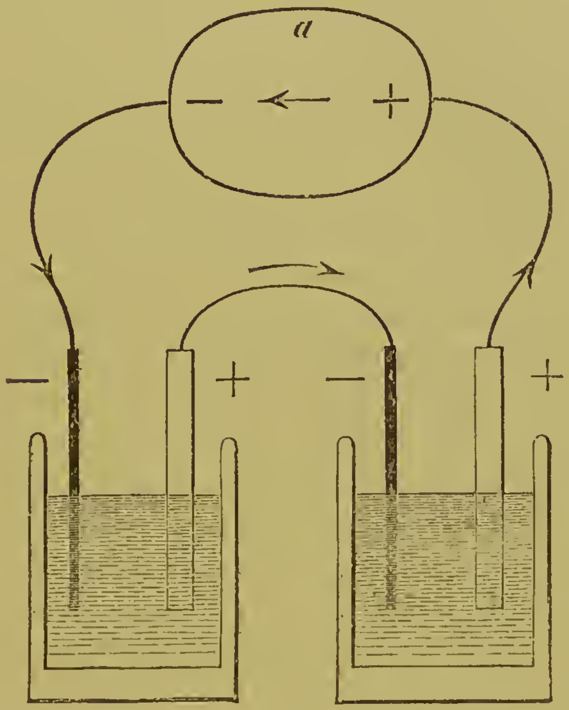


FIG. 4.—Diagram showing the human body, *a*, introduced into the circuit.

and the poles are called *electrodes*; they vary much in form, according to the special requirements of every case.

Electrotherapeutics consists simply in placing the human body—usually a part of it only—into the external circuit of an electrical current; in other words, in submitting it to a current brought to it through the electrodes, and of variable strength and duration, with or without interruptions or other changes. You see what an endless variety there must be in the methods of application. The art of the electrotherapeutist consists in choosing the proper mode of applying the current in each individual instance; a clear conception of the physical conditions of the process must obviously be of primary importance in these electrical manipulations.

The chief condition to be fulfilled by a galvanic battery for electrotherapeutical purposes is, therefore, that it shall yield currents of sufficient strength, durability, and uniformity through the human body, such as can be readily conveyed to it by means of appropriate electrodes. We shall presently consider the accessory apparatus required for medical uses.

Faradism.—Under this name we may consider together induction currents furnished either by magnets or galvanic currents, since both kinds are essentially of the same nature.

Currents may be produced by the action of magnets upon a closed conducting circuit (such as a spiral or coil of wire of which the ends are connected together) by suddenly bringing near or removing a bar magnet from it. At both events currents are generated, of opposite directions to one another. These currents are the stronger the more powerful the magnet, the more rapid the movement, the more numerous the turns of wire in the coil. If the human body be intercalated between both ends of the spiral, the currents flow through it and may thus be utilised for physiological or therapeutical purposes. The construction of the so called *magneto-electric* or rotary apparatus rests upon this principle; a rotating horse-shoe magnet is rapidly brought near to and removed from a spiral, whereby numerous currents, in rapid succession and alternately opposite directions, are generated. Their action in the organism is very marked. We need lose no time by going more deeply into the structural details of these apparatus, the use of which has for a long time been given up in medicine, their place having been taken by the more convenient galvano-electric induction apparatus.

Galvanic currents are, through their inductive property, a ready means of producing currents similar to those just described. If, instead of a magnet, you bring quickly in the neighbourhood of another closed spiral a spiral of wire in which a galvanic current flows, a current is generated in the latter of opposite direction to the galvanic current. If now you quickly remove the inducing spiral, another current, in the same direction as the galvanic current, is generated in the other spiral. Exactly the same effect is produced if the two spirals remain at the same distance from one another, and a galvanic current is suddenly sent through the one (the *primary* coil)—in other words, brought near from an infinite distance. An induced current is then generated in the other or *secondary* coil. A similar phenomenon occurs when the galvanic current is broken, i.e. removed to an infinite distance. We may then, by suddenly closing and opening the circuit in the primary coil, obtain induction currents in the secondary, flowing in the first case in the opposite direction to, in the second in the same direction as the inducing current. These induced currents are the stronger the stronger is the primitive current, the greater the number of turns in the two coils, and the nearer the two coils stand to one another—strongest therefore when the one is completely included within the other.

When the makes and breaks, i.e. closures and openings, of the current in the primary coil succeed one another with great rapidity, we obtain in the secondary spiral a continuous succession of currents, of alternately opposite directions. Such currents, produced by galvanic induction, are now generally called *faradic* in electrotherapeutics. If you include the human body in the circuit of the secondary spiral, they circulate through the tissues and there display their physiological properties. All such currents have an extraordinarily short duration; they are almost instantaneous.

Numerous forms of induction apparatus have been devised; in the ordinary kind the currents induced by the makes and breaks in the primary circuit are of unequal strength. The make induction current, generated in the secondary coil by the closure of the inducing current, is delayed and weakened by an 'extra current' induced at the same time in the primary; whilst at break this extra current cannot circulate, and hence cannot influence the break secondary current. Every make secondary current is therefore followed by a stronger break secondary current. The difference between the two is considerable, as you can readily find out for yourselves by holding the electrodes of the secondary spiral and producing single makes and breaks in the primary circuit. At every break you experience a lively shock, at every make a very weak one or none at all. By means of a special modification in the apparatus this difference can be eliminated (Helmholtz's arrangement); but this arrangement is not available in apparatus intended for therapeutic uses.

The break induction current has thus such a predominance in its effects on the body that it alone need be considered by us; we may consistently speak of it as alone existing, and determine the polarity of the faradic electrodes by reference to its direction. By anode and kathode of the secondary induction coil we mean the positive and negative poles of the break current, though from a theoretical point of view we must remember that each electrode is successively anode and kathode.

The effect of the inducing current is notably increased when combined with that of the magnet. If a bar or bundle of rods of soft iron be inserted into the primary coil it is magnetised on making the current, demagnetised on breaking it; and the effect of this magnet (instantly brought near from an infinite distance, and instantly removed to an infinite distance) is added to that of the inducing current. Hence you see that a core of soft iron wires is included within the primary coil of the usual induction apparatus.

All such apparatus possess a contrivance by which the interruptions (makes and breaks) of the inducing current—usually supplied to the primary coil by one or two galvanic elements—are carried on automatically. A spring is set in movement by the magnetisation of the core, and its vibration rapidly makes and breaks the contact through which the inducing current flows. The principle of this mechanism, which renders induction apparatus automatic, is always the same though the details of construction offer many variations and include contrivances for regulating the speed of interruption. You will best study these details by examining the apparatus themselves.

I must mention one more point here—namely, that induction phenomena occur in the primary coil itself, inasmuch as every turn of wire acts upon all the others. We cannot make use of the currents so generated when the primary circuit is closed; but on opening it the induction current may readily be collected by an appropriate arrangement, and applied to therapeutic purposes. This is the so called *extra current*. It is a true induction current, though generated in the primary coil, and has been called the *primary faradic current*, in opposition to the *secondary faradic current*, or current generated in the secondary coil. Hence the fundamental principle of induction apparatus is that by means of the rapid interruptions of a galvanic current flowing through the primary coil induced currents are generated in both secondary and primary coils, and these may be sent through the human body by means of appropriate arrangements. Graduation of such currents is effected in various ways, such as by pushing the coils towards or from one another, by moving the core of iron wires in or out, &c. The point which you must always keep clearly before your eyes is that you always have to do in the induction currents with a large number of successive and rapid fluxes of instantaneous duration—very different from the uniform and equal flow of the 'constant' or galvanic current.

Addressing myself now to the usual inductoriums and batteries, I shall give you a short account of their principles rather than of the details of their construction. It seems to me useless to enter upon a description of all or even a few of the innumerable and more or less practical forms now in existence. I shall rather insist upon the conditions which such apparatus must fulfil, and then pass to a fuller account of the indispensable accessory apparatus required in medical applications.

The first condition required from an induction apparatus is that it shall have large enough coils to yield sufficiently strong currents, and that the length and thickness of the primary and secondary wires have an approximate relation. Secondary coils of very fine wire always appear to me to yield more painful currents. Provision must be made for the ready use of either the primary or secondary current and for the adequate graduation of both. Finally, the automatic interrupter must act regularly and at the required rate; the galvanic elements must have sufficient electromotive force and durability to furnish the necessary current; and the primary coil must have a sufficient number of turns of wire of the required thickness.

These conditions are more or less fulfilled by the numerous apparatus now generally in use. In all scientific researches, and in medical application at the physician's house, the best form is the well-known 'sledge' of Du Bois-Reymond, such as is commonly met with in physiological laboratories. This form of instrument is made with various but unimportant modifications, and is supplied with a scale which it is best to graduate so as to have its zero at the point where the two coils are completely within one another.

For other purposes, especially for those of practice out of doors, portable apparatus which are constructed so as to be readily carried about are the best. They consist of a box containing the galvanic elements as well as the induction apparatus proper. The coils are placed horizontally or vertically, and are provided with some means of graduation, and not unfrequently with a scale to determine the graduation. There is no lack of instruments of this kind, large and small, more or less convenient. Stöhrer's model has long been familiar to electrotherapeutists. Numerous other firms supply reliable machines of pretty uniform quality.

The zeal of instrument makers and the fancy of inventive physicians have brought forth innumerable forms of very small (so called pocket) apparatus, which are light, handy, applicable to many cases in practice, but are of no use for more accurate work, such as diagnosis, and do not stand the wear and tear of active use. The pocket apparatus of Gaiffe, Trouvé, and others may be mentioned as typical of the kind.

The cost of an induction apparatus ranges from about 1*l.* to 10*l.*, according to its size and completeness. In choosing one it is advisable to be guided less by the cheapness than by the solidity of construction, the general usefulness and durability of the instrument.

For the purpose of *galvanic batteries* any element may be used, provided it is well constructed and in good working order. The choice extends from the older Daniell's, Grove's, and Bunsen's cells to the more recent ones of Stöhrer, Siemens-Halske, Muirhead, Smee, Gaiffe, Leclanché, &c. But in practice it is found that cells vary greatly in their relative applicability to our wants according to their prime cost and working cost and the manipulations required to handle, charge, and clean them.

I must not, however, fail to mention one point, viz. that absolute constancy is by no means a necessary requirement for elements used in ordinary practice. The stress laid by theoretical electrotherapeutists and instrument makers upon the importance of such a constancy does not rest upon any solid grounds. A constancy such as we require in our applications to the body, of three to five or ten minutes at most, is secured by the use even of the most 'inconstant' elements; whilst, on the other hand, the constancy of the most perfect cells is rendered illusory by the numerous causes of variation in the current strength introduced into the circuit as soon as the living body forms a part of it. I may mention, among the latter, increasing permeation and conductivity of the skin with the duration of the current, changes of resistance with changes of temperature of the media, and of the nature and quantity of the moistening liquid applied to the electrodes; polarisation of the electrodes and possibly of the tissues themselves, &c. The constancy of the elements is of importance only with reference to the durability and reliability of the battery as a whole, but is by no means an absolute necessity for short and intermittent periods of use with relatively weak currents, and may be more than compensated by other advantages possessed by 'inconstant' elements.

An ordinary medical battery should be of moderate cost and easy to handle and keep in order; durability of cells, facilities for taking out the cells and replacing them, convenience in placing into circuit rapidly and without interruption the required number of cells, are other desirable characteristics of such an instrument.

During the last few years great improvements have been carried out in this direction by the combined efforts of electricians and physicians, and we have now a large number of batteries made up of various elements (Stöhrer, Leclanché, Siemens-Halske, Gaiffe, &c.) which leave little to be desired. A choice among them cannot be directed by any absolute principle: there is no battery which is 'the best' of all. Habit and taste also enter into account in the formation of individual judgment concerning them.

There is still a difficulty which has not been overcome, viz. the construction of a thoroughly portable battery which shall at the same time be quite reliable and durable. Much progress, however, has already been made in this direction, and batteries exist which are portable enough, though not free from inconveniences. Notwithstanding that, as we shall see in the next lecture, cells for therapeutical purposes may be made as small as we wish, and yet remain capable of yielding currents of sufficient strength; still there are practical limits to this reduction of size, due to the perishability of such small cells and to the necessity of frequently replenishing them. It would be interesting to try whether elements of the same size but of different construction and elements of the same construction but of different size vary in their physiological and therapeutical effects. From a purely physical point of view it is impossible that it should be so, but there are electrotherapeutists whose opinion and reported results tend to such a belief.

I have not any personal experience of all the kinds of batteries made, but I think that good results are to be obtained from the use of any with the manipulation of which its owner has become familiar. I still prefer for the requirements of ordinary practice the cell made popular by Stöhrer both for large and for portable batteries, with its recent improvements and imitations. Large batteries for the hospital and consulting room may be composed of Leclanché or some form of Daniell elements, though they require the assistance of a competent workman for recharge or repair.

LECTURE III.

Accessories — Collector — Commutator — Galvanometer—Measurement of the Absolute Current Strength—Rheostat—Rheophores—Electrodes and their Various Forms—Electrisation Table—Physical and Physiological Determination of the Poles.

Gentlemen,—In order to turn to advantage the current generators just described you require a number of accessories. They must be well constructed and skilfully handled before the current can be conveniently and accurately applied in diagnosis and treatment. Let me advert briefly to these apparatus.

By the term *collector* is meant a very necessary contrivance which enables us to throw into, and take out of, circuit any number of cells, preferably without interrupting the current when once made. For this purpose a number of contact studs, corresponding to the number of cells in the batteries and capable of being brought into connection with the wires leading to the electrodes, are suitably disposed. The mechanisms by which this is effected are numerous; there may be springs of contact fixed to a movable sledge or to a revolving switch, arranged so as to touch the next stud before leaving the previous one; or there may be plugs, two in number, of which the one is fixed to the next stud before the other is removed. The most complete collector is one which allows of every cell being taken singly; this is, however, often possible only for a small number of elements, and larger numbers must be taken by threes, fives, or even tens.

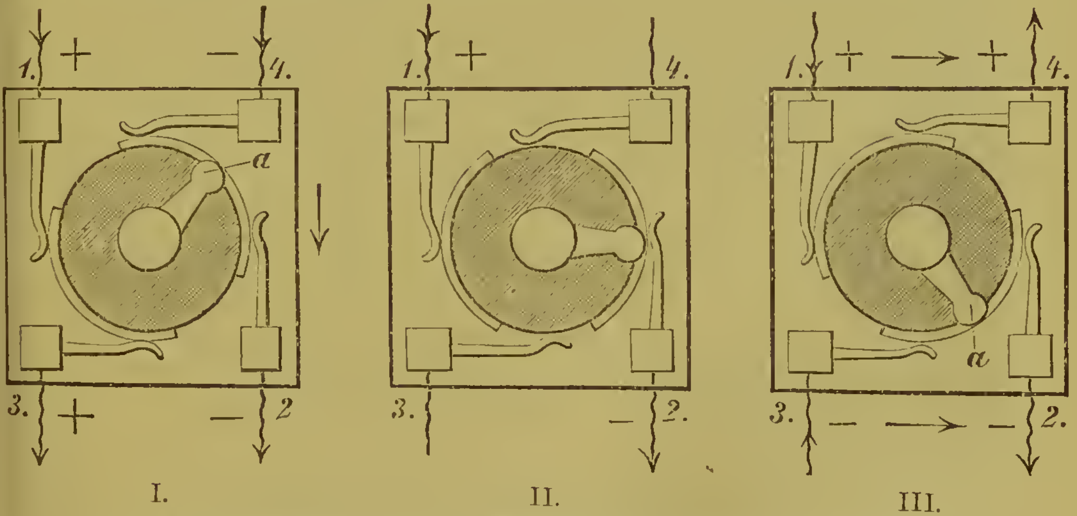


FIG. 5.—Diagram representing the commutator with the vulcanite disk (movable by means of the handle) in three different positions. Contacts 1 and 2 connect with the battery, 3 and 4 with more distant points in the circuit. In I. the anode is at 3, in III. at 4, and the current is therefore reversed through the circuit. In II. the circuit is open.

A very important accessory, indispensable for all except the roughest work, is the *commutator*, well known in the physiological laboratory. It consists of a contrivance introduced into the external part of the circuit for the purpose of reversing the direction of the current beyond it. It may be arranged so as to perform simple interruptions of the current in either direction, as well as the commutation or change of direction of the current. A form of it (introduced by Siemens and Halske, improved by Brenner, and now commonly used in Germany) is represented diagrammatically in fig. 5. A revolving disk of vulcanite has two strips of metal so fixed to its periphery as to leave a gap of about one centimetre between their extremities. Four contacts serve to connect it with the poles of the battery: 1 and 2 are so connected (anode +, kathode —). The electrodes are attached to 3 and 4. Each strip of metal serves to connect two contacts, one of each pair. Thus in fig. 5, No. I., 1 and 3 and 2 and 4 are connected with one another respectively; the current now flows from 1 to 3, which is thus the anode, and after passing through the external circuit, including the human body, returns through 4 to 2. The kathode is 4 and the current flows from 3 to 4.

Give a quarter-turn to the disk with the handle *a*, so as to make it assume position III. You see now that the direction of the current is changed. Contact 1 is connected with contact 4, and contact 2 with contact 3; 4 has become the anode, 3 the kathode; the current travels through the body from 4 to 3. You have effected a reversal of the current, a commutation.

If, however, you give the handle the eighth of a turn only, so as to place it as in II., two of the contacts touch the free spaces between the extremities of the metallic strips; the circuit is opened. You can then at wish close and open it in either direction without effecting a commutation. You can make either 3 or 4 an anode or a kathode, and through the electrode attached to either and fixed to a determined point of the body bring that point under the influence of an anode or a kathode, producing either a kathodic closure (make) or an anodic closure and a kathodic opening (break) or an anodic opening. You can likewise reverse the current and effect a change from kathode to anode and from anode to kathode at that same point.

Brenner has modified the commutator so as to diminish at wish the free spaces between the strips, and so produce very rapid commutations, which is advantageous for many diagnostic purposes.

The commutator is indispensable for carrying out electrical examinations, which, as we shall see later on, require repeated closures and openings of the current as well as commutations. The instrument may vary in plan or detail of construction, but the main principles are the same in all kinds, and we need not say more about them. Commutators which do not permit the effecting of simple makes and breaks of the current cannot be of any use for electrodiagnostic purposes, unless supplemented with a special arrangement for interrupting.

An instrument absolutely necessary, not only for accurate investigations, but also in daily practice, is a good *galvanometer*. Previously galvanoscopes were used only to show whether any current at all was passing; the necessity, however, of *measuring* currents in diagnosis and treatment is becoming daily more apparent and the galvanometer is adapted to that purpose. I was the first to insist upon the fact that quantitative estimations of the excitability of nerves and muscles, to electrical currents, can be estimated only by means of a galvanometer; the mere indication of the number of cells used, or of the units of resistance intercalated in the circuit, is utterly insufficient and erroneous. I had a galvanometer constructed (with a vertical needle and on the same principle as the multiplier) which is not costly; it possesses four graduations of its sensibility, and thus allows of measuring widely different current strengths, which is a great convenience for all diagnostic purposes. This instrument met with a pretty general acceptance in Germany, but had a disadvantage, viz. that the numbers given by each galvanometer are not comparable with those of any other instrument, even if made on the same model. The deflections vary greatly with the sensitiveness of each needle, so that the data obtained by different observers cannot be directly used for mutual comparison. In addition to this the deflections are approximately proportional to the strength of current only when small; beyond a certain point they increase much more slowly than the current required to produce them.

Efforts have lately been made to remove these deficiencies by constructing galvanometers which show the absolute strength of the current. Such instruments are empirically graduated so as to indicate this strength in terms of an accepted unit, so that one can, at a direct reading, say, This is a current of 6 or 10, or 20 or 25 units of strength. Owing to the diminishing influence of the current upon the needle as it is deflected from the vertical plane of the coil, the divisions of absolute strength become more and more crowded together. The milliweber, now called the milliampère (ma.), is the unit according to which all the new absolute medical galvanometers are being graduated, since the International Congress of Electricians of 1881 recommended its adoption.

The ampère is the unit of current strength in the new system of electrical measurements. It represents the strength of a current of electricity impelled by an electromotive force of one volt through the resistance of one ohm. But, as it is much too large for our purposes, its thousandth part has been adopted as unit; one ma. is equal therefore to $\frac{1 \text{ volt}}{1000 \text{ ohms}}$.

There is a great advantage in being able to express by simple numbers (5, 10, 20 milliampères, for instance) the strength of the currents used in testing the excitability of nerves; to compare the results of others with our own; to control exactly the currents used in treatment, and to have a dosage of electricity as of every other therapeutical agent.

The matter, however, is not so simple as it may appear; there are many difficulties to be overcome before we can make full use of these advantages. It is true that the technical difficulties met in the construction of a good galvanometer are nearly overcome. We first had the imperfect instruments of Gaiffe and Stöhrer; those of Edelmann are somewhat too delicate for common use. The ordinary vertical galvanometers are too much exposed to the disturbing influence of the earth's magnetism; but Hirschmann seems finally to have produced one which fulfils most of the desiderata, since it is free from the last-named drawback, for it does not require to be placed vertically to the magnetic meridian in order to yield accurate readings. Müller asserts this instrument to be perfect, but its oscillations are too considerable for use in electrodiagnosis. Edelmann's galvanometer appears to me to be the best both as a sensitive and as a dead-beat instrument. A vertical scale recently introduced removes the objection arising from the difficulty in reading on the horizontal dial. Unfortunately it is costly and not portable.

It is highly necessary not to lose sight of the fact that the density is not entirely dependent upon the strength of the current, and that its importance, physiological and therapeutical, is paramount. Anyone who has considered the matter must see that the effect of a current of 5 milliampères, for instance, is quite different when it reaches the body through an electrode of 1 square centimetre surface, from when it does so through an electrode of 20 centimetres. No definite knowledge is imparted, therefore, by saying that a nerve reacts to a current of 2 milliampères, or that the spinal cord must be treated with a current of 10 milliampères. An accurate description of the size and shape of the electrodes, and of their points of application, must be added before the statement of the current strength can be of any practical value. The recent work of C. W. Müller contains a valuable suggestion with reference to this point. He expresses the density[1] of the current at the point of contact of the body with the electrode, by a fraction, of which the numerator is the strength of current in milliampères, and the denominator the number of square centimetres of surface of the electrode. Thus when we speak of a current of $\frac{1}{18}$ or $\frac{5}{30}$ we mean that a current of 1 or 5 milliampères entered the body through an electrode of 18 or 30 square centimetres respectively. We cannot do better than to adopt this method; but we must not fall into the illusion that we ever can attain a dosage of mathematical precision—an impossibility under the conditions which govern electrotherapeutical applications.

In order to graduate the current more finely and smoothly, efforts have been made to adapt the *rheostat* to the requirements of electrotherapeutics. Resistant bodies, such as columns of liquid (water, salt solutions, &c.), have been introduced into the circuit itself; by others, resistance coils (Brenner's plug rheostat) have been placed in a derived circuit, so as to diminish the main current by diminishing the resistance and vice versa. All these instruments fulfil their object in a very imperfect manner. The action of liquid rheostats is uncertain on account of electrolysis and polarisation; they act well when but few cells are in circuit, and are of use, only, where the sudden change in the current strength, by throwing into or removing from circuit the number of cells between consecutive

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[1] In accordance with the definition of the term,

$$\text{density} = \frac{\text{strength of current}}{\text{diameter of conductor}}.$$

studs of the collector, has to be modified. Glass tubes filled with a 40 per cent. solution of sulphate of zinc, with zinc electrode inside, are well suited for this purpose. Moistened strings, or bands of some tissue, are occasionally serviceable.

The plug rheostat, especially in its primitive form (viz. with three circles of contact studs), does not allow of a smooth graduation, and is of no assistance in measuring the strength of the current, since, with every change of resistance in it, the total current is altered, and therefore an unknown fraction of it reaches the body in the main circuit. Moreover the effect of the rheostat, on the current of different batteries, varies, perhaps owing to the varying internal resistance and polarisation of the elements; and the instrument is dear and inconvenient to manipulate. The introduction of a switch has diminished the last drawback, and in Holst's modification arrangements are made to increase or diminish the resistance by only 20 ohms at a time and without sudden jerks.

On the whole, no satisfactory rheostat has yet been devised, and we still are in want of some instrument yielding a fine, smooth graduation of the current.

In order to carry the current from the commutator to the electrodes, we use conductors which are called *rheophores*. They must be as thin as possible, flexible, tough, and should measure from 1·50 to 2 metres in length. They are best made of very fine copper wires, and must be thoroughly insulated in order to prevent short circuitings when accidentally wetted and brought into contact with one another. Fine indiarubber tubing is the best material for the purpose. It is important that they should be firmly connected with the terminals of the battery and with the electrodes; for this purpose they should carry at their ends strong pins to which their wires are tied and soldered.

The current is applied to the body itself by means of *electrodes*. Much depends upon their shape, size, and composition; one often meets with electrodes which are unsuited for their purpose. The choice of electrodes must be governed by the end one has in view, and it is dictated by physical considerations, as we shall see by-and-by.

I prefer metal electrodes, made of brass and strongly nickel-plated, though carbon ones may also be used. Some are knob-shaped. The best covering for them is a moderate thickness of fine sponge: wash-leather is not so good. Others are in the form of plates, padded with soft flannel and covered with linen. The plates may be quadrangular or rounded; their edges must be somewhat turned up, or they may be concave and large. An important point is to prevent the metal from protruding at the edges and corners.

The size of the electrodes varies greatly with the use to which they are to be put. In order to localise the current upon single points, such as small nerve trunks, motor points, &c., small button-like electrodes are to be used with a diameter (including the sponge cover) of not more than half a centimetre ($\frac{1}{5}$ inch); we shall henceforth call them the *fine* or *smallest* electrodes (fig. 6, *a*). The next in size, used for the excitation of the larger nerve trunks, of muscles, for the electrisation of the eye, face, neck, &c., may have a total diameter of $1\frac{1}{2}$ to 2 cm. ($\frac{3}{5}$ to $\frac{4}{5}$ inch), and will be called the *small* electrode (fig. 6, *b*). Then comes the electrode appropriate to the galvanisation of the

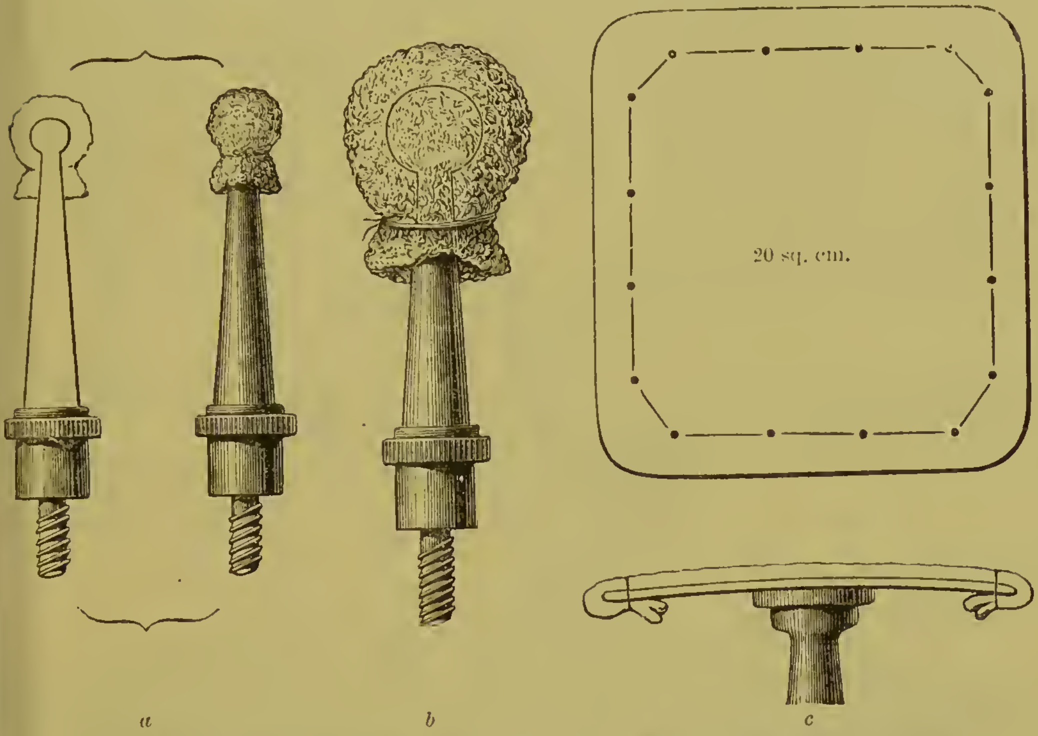

FIG. 6.—Various forms of electrodes (actual size). These are adapted to the handle represented in fig. 7. *a*, 'fine,' or the smallest electrode; *b*, 'small' electrode; *c*, 'medium' electrode, slightly convex on the surface and rounded at the corners. All are of nickel-plated metal; *a* and *b* covered with sponge, *c* with flannel and linen.

face and neck and the localised galvanic excitation of nerves and muscles—a flat square electrode of 20 square centimetres surface (4·5 cm. nearly, or 2 inches side), which I call the *medium* electrode. Finally there is the *large* electrode, which is used for the applications to the back for diseases of the spinal cord, for sciatica, for diseases of the large joints, and in electrodiagnosis as 'indifferent' electrode. It consists of a rectangular, concave plate, as shown in the figure (fig. 7, A and A′), and measures 50 square centimetres area (5 × 10 centimetres side, or 4·5 × 2·25 inches). Larger plates still (100 to 150 sq. centimetres surface) may occasionally be wanted: *very large* electrodes. I have used some of considerable size in the case of very fat people or for other special purposes. Lately I have employed for the galvanisation of the head, in various cerebral disorders, very large electrodes (100 sq. cm. surface, or 14 × 7 cm. side—5·5 × 2·75

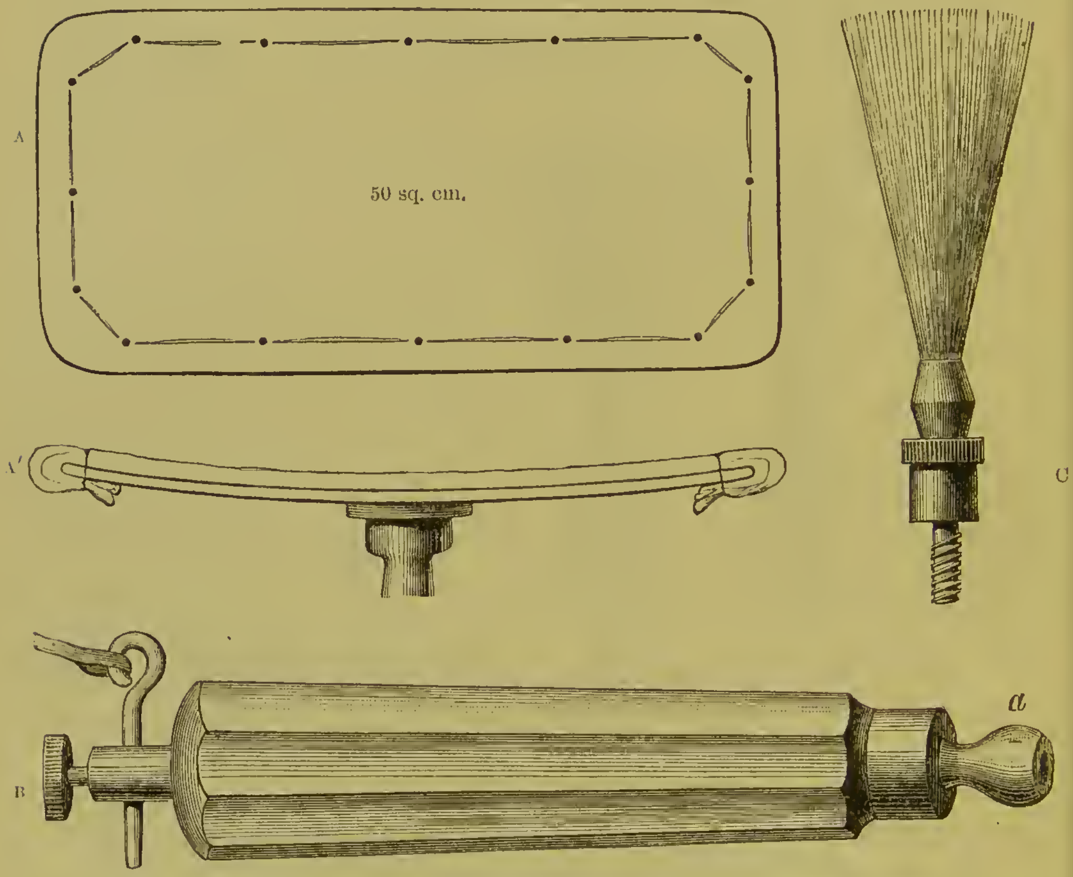

FIG. 7.—A, large electrode (10–12 cm. × 5–6 cm.); A′, the same in section, to show its curvature; B, handle to which all the electrodes may be fitted at the point *a*; its entire length is about 16 centimetres; C, electric brush.

inches), curved so as to fit the convexity of the skull and covered with a thick layer of sponge. They are well adapted to their purpose, and I shall henceforth call them the *large head electrodes* (fig. 8).

Most of these electrodes may be made of compressed carbon, but their appearance is inferior to the metallic ones, and possess no advantage over them, and when large are very inconvenient, owing to their thickness and rigidity.

I shall have an opportunity further on of speaking of the 'normal exploratory electrode,' which I propose for general adoption and which should measure 10 square centimetres—that is, about 3·5 centimetres diameter if round, 3·2 centimetres side if square. When electrodes differing in size from the above are used it is best to choose them of such length and breadth that their surface can be approximately expressed in a round number of square centimetres, such as 30, 50, 80, and so on.

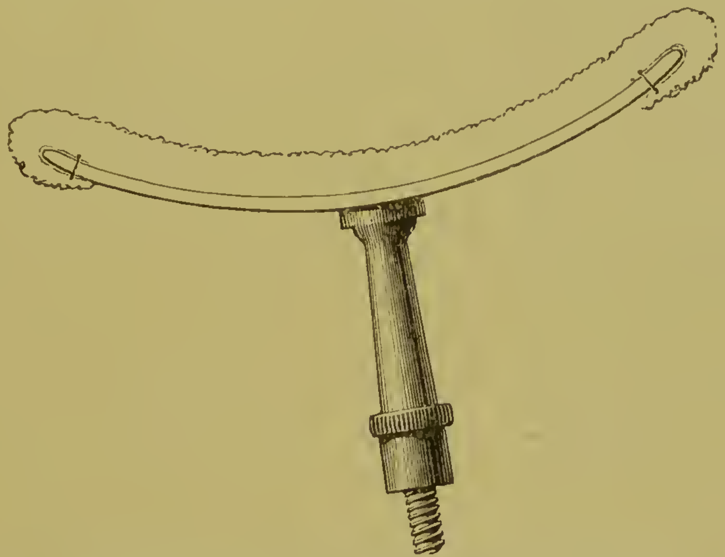

FIG. 8.—Large head electrode (14 cm. × 7 cm., 100 sq. cm. surface), seen in section. It is made of flexible metal and covered with a thick layer of soft sponge.

The electrodes must be screwed into solid handles, of which the shape and size may be left to the individual fancy and custom. I prefer the larger and stronger ones (fig. 7, B). It is immaterial to which end the rheophores are fixed; I find it more convenient to have them attached to the upper end. Handles fitted with an interrupting apparatus are very convenient for many purposes, as they allow the current to be made and broken by pressure of the finger whilst the electrode is held immovable. Most instrument makers supply more or less simple and practical interrupting handles.

Whenever the electrodes are applied to the body they must be thoroughly moistened; for both they and the epidermis are insulators, or bad conductors, when dry. It is best to use hot water for the purpose. Cold water does not conduct so well, penetrates the epidermis much more slowly, and is unpleasant to most patients. Salt water, which conducts much better, has so many inconveniences (oxidation of electrodes by electrolysis, irritation of the skin, soiling of clothes, &c.) that I have long ago abandoned its use, except when the extraordinary resistance of the body so diminishes the current strength as to prevent the desired effect.

Hitzig has employed and recommended unpolarisable electrodes for therapeutical purposes, on the ground of their giving rise to less pain. They have failed to come into general use, because their advantages are more than outweighed by the complicated manipulations they require. Single plates of amalgamated zinc, padded with sponge, soaked in a solution of sulphate of zinc, and covered with linen, may be used for the purpose.

In addition to the electrodes above described you will want some of special form, and among them, particularly, a dry metallic electrode and one made of wire, like a brush (fig. 7, c). The treatment of the urethra, bladder, uterus, rectum, larynx, &c., requires appropriate instruments, consisting chiefly of long metal rods covered with indiarubber, tipped with knobs of various sizes, according to the purposes they are intended to fulfil.

This is about all the apparatus you need for most of the practical, and even scientific, requirements of electrotherapeutics. It is convenient to have them arranged in such a way as to have them all under immediate control. Various patterns of 'electrising tables' have been made for this purpose, more or less elegant and complete. They often include needless complexities and are patronised chiefly by specialists that delight in elaborate, showy, and costly apparatus.

For my own part, I prefer to work without complicated apparatus, whenever it can be done, and have been in the habit of placing on a strong table my battery of thirty cells (Stöhrer's), with an induction apparatus (sledge), a galvanometer, a rheostat, and a commutator, the whole being disposed so as to be readily under command from my seat. A small apparatus, with simple metallic plugs, allows of sending the (primary or secondary) faradic current or the galvanic current through the same electrodes, which are attached to a single pair of binding screws on the table. The current alternator-combiner-reverser devised by de Watteville, which allows of taking either faradic or galvanic current, or both together, and to reverse them also, is still more convenient. These various instruments are connected together by wires running under the table, the top of which is movable. Plugs throw the galvanometer and the rheostat in and out of the circuit. A vessel containing hot water is fixed to the front of the table, and a drawer contains the small accessories and electrodes. The total cost of such a table ranges between 15*l.* and 18*l.*

Before I leave this subject, let me say a word on the determination of the poles, which is often required to be made when the connections cannot be followed out. The easiest methods are the test of blue litmus paper, which the positive pole, or anode, turns red; and that by electrolysis of iodide of potassium. Starch is moistened with a solution of the iodide, and the ends of the rheophores dipped into it; a vivid deep blue colour is produced at the anode, through the liberation of iodine. This test is not applicable to faradic currents, which do not effect electrolysis (unless of enormous strength), without the assistance of special arrangements (single break shocks; discharge by sparks). The physiological effects of the two poles serve to discriminate them as accurately as their chemical action; the negative pole, or kathode, placed on a motor nerve, excites, when the current is made, a much more powerful muscular contraction than the anode. The anode produces on the tongue a more marked sensation of taste when the poles are placed upon the cheeks. Many people can also determine the polarity of an electrode by observing the quality and colour of the flash produced when it is applied to the eye. You see that we have means enough for the discrimination of the galvanic poles whenever required. The kathode of the faradic break current can also with ease be recognised by its greater effect upon motor and sensory nerves.

LECTURE IV.

Physical Laws of Current Diffusion and their application in Electrotherapeutics—Ohm's Laws—Current Strength—Resistance in different conductors—Resistance of Animal Tissues, and of the Epidermis in particular—Differences obtaining between Individuals, and the Consequences of These—Internal and External Resistance—Inferences as to the Construction of Apparatus—Current Density and the Laws by which it is determined—Practical Conclusions with reference to the various Requirements of Electrotherapeutics—Electrolytic and Cataphoric Effects.

In the great majority of cases, the main object of electrical applications is to localise a current of definite strength, density, and direction, in a diseased portion of the body. Either both, or more usually, one pole only, is applied upon the part to be tested for diagnosis or submitted to a curative influence.

We have already studied the sources of the currents and the apparatus necessary for their convenient application to the human body. To-day we have to enquire how we conduct a current into the human body, and how we can localise it as we want, upon certain points of it. It is necessary, therefore, that we should recall to our minds the laws of diffusion in conducting bodies. The human organism is nothing but a mass of conducting substance, of definite resistance, and behaves with reference to electrical diffusion exactly like any other such mass.

Those laws—well known under the name of Ohm's laws—are of the highest importance in electrotherapeutics. It is only by keeping them before your minds, and acting in intelligent accordance to them, that you will be able to make a truly rational and scientific use of the current. No other principle in electrophysics can be compared with them in importance from our point of view; and you must therefore be thoroughly conversant with them in all their aspects and applications. I must, however, confine myself here to recapitulating these laws briefly, and leave it to you to fill up the outline.

1. The intensity of the current, or better the *current strength* (C), depends first upon the *electromotive force* (E) of the apparatus used for its generation (i.e. upon the metals and

liquids used in the cells and the difference of potential between them, upon the force of the inducing magnet and the number of turns in the coils, &c.) All other conditions being the same (external circuit, form of generator, &c.), the current strength is directly proportional to the electromotive force of the battery or other source of electricity.

Now the several kinds of cells and arrangements of cells differ in their electromotive force—a circumstance which must not be lost sight of when a choice has to be made. When a certain current strength is wanted—and in electrotherapeutics it must not fall below a certain average—elements of a relatively high electromotive force and coils of fair capacity must be chosen. These conditions are fulfilled by the apparatus commonly used.

2. You will soon find that, with equal electromotive forces, the nature of the external circuit influences greatly the strength of the current (as measured on one of the instruments devised by physicists for that purpose). The reason of it is that the external circuit offers a certain *resistance* (R) to the current, which varies with the constitution of the external circuit; and with every change in this resistance a change in the current strength must obviously occur. The law which embodies this fact is expressed by saying that the strength of the current is inversely proportional to the resistance in the circuit.

We may reduce the two statements just made to the single expression that the current-strength is equal to the electromotive force divided by the resistance: $C = \frac{E}{R}$. This proposition is of the highest practical importance; for, as we shall see, we have to deal in the body with considerable resistances; so that, in electrotherapeutics, generators endowed with a relatively large electromotive force yield comparatively moderate currents.

3. Further investigations will show you that it is not only the *quality* of the conductor in circuit (i.e. the substance of which it is made, such as metal, liquids, organic tissues, &c.) but also its *shape* which influences the resistance offered to the current. If you take, for instance, a given mass (say 500 grammes) of copper, and turn it now into a short thick cylinder, next into a wire 50 yards in length, you will find that the

resistance of the wire is very different from that of the cylinder. Experience, indeed, has shown that *the resistance of a conductor is directly proportional to its length* (i.e. increases with every increase of its length), *and inversely proportional to its diameter* (i.e. increases with every diminution of its diameter). Hence it follows that *the current strength* (cf. prop. 2) *diminishes with every increase of length in the conductor* (i.e. is inversely proportional to its length), *and increases with every increase of diameter* (i.e. is directly proportional to its diameter). The current is, *cæteris paribus*, the stronger the thicker and shorter the conductor in circuit; the weaker the longer and thinner that conductor.

From these important propositions certain consequences immediately follow, which must be gone into with some detail, on account of the great importance, from an electrotherapeutical point of view, of the facts involved. The various conducting bodies offer very different resistances to the passage of the current; the metals are by far the best conductors, silver having the least resistance of all. Next come copper, gold, zinc, iron, platinum, German silver, &c.; mercury has the highest resistance (about 50 times that of silver), and is used in the construction of Siemens's standard unit of resistance, which consists in a column of mercury 1 metre high and 1 sq. mm. surface area (= 0·95 ohm nearly).

Liquids offer much greater resistances than metals. Solutions of salts and dilute acids conduct 10,000 to 300,000 times less than mercury; pure distilled water is said to have 120,000,000 times the resistance of mercury, but the admixture of a mere trace of a salt or an acid to it diminishes this number considerably.

Animal tissues belong to the class of conductors of which the resistance is considerable. They may be considered from our present point of view as saline solutions of variable concentration, for their conductivity depends upon the blood and interstitial liquids which saturate them. The various attempts at determining the resistance of the several tissues themselves (nerves, muscles, glands, bones, &c.) have led to very discrepant results. According to Eckhard, muscle is the best conductor of the body, and its resistance is half that of nerves, tendons, and cartilage. The resistance of bone is thought to be 16 to 22 times that of muscle.

Other observers found other numbers. Ranke found that the resistance of living nerve and muscle is about the same, but that dead rigid muscle conducts twice as well. Hermann, on the other hand, finds that the resistance of living muscle is less than that of all other tissues; Harless states the resistance of nerves to be 15 times less than that of distilled water; he estimates it to be about 115,000,000 times that of copper.

From all these data we may conclude that the difference of conductivity between the several animal tissues varies within comparatively narrow circuits, and that inside the warm living body they present resistances corresponding to and varying with the amount of blood and other liquids they contain. The best conductor of all appears to be the muscular tissue. Bone, which is permeated with a network of fine vessels, has evidently a higher conductivity than that erroneously ascribed to it. Its resistance does not preclude the current from penetrating into the cranial or spinal cavities, as was formerly assumed.

We must bear in mind that nerve and muscle offer a much greater resistance to currents traversing them transversely than longitudinally (5 to 1 in nerve, 9 to 1 in muscle according to Hermann). Imbibition of saline liquids does not, therefore, seem to determine resistance altogether, but the internal polarisation which occurs as soon as the current passes must play a considerable part in the matter.

In electrotherapeutics we usually have to do not with exposed tissues, but with parts covered with their integuments (the skin and epidermis), and this is a circumstance of the highest importance, though too often left out of sight. The chief resistance of the human body to the current is usually offered by the epidermis, and in presence of this resistance every other may be left out of consideration. It is this resistance of the epidermis which practically determines the strength of current sent by a definite electromotive force through a given part of the body, though it does not determine the diffusion of the current through the deeper tissues.

The epidermis consists of two layers, the horny and the mucous. The latter consists of soft cellular elements and presents the same resistance as the other animal tissues. The former consists of dry, horny cells, and might be considered almost as an insulator—that is, as a body presenting an enormous resistance to the current—a fact which you can easily demonstrate upon the thickened dry epidermis of the heel or palm. Saturation with hot water or salt and water converts this horny layer into a conductor.

If this horny epidermis were to cover the whole body with perfect uniformity the percutaneous application of electricity would be made very difficult; at any rate we should require more powerful apparatus. But, apart from the microscopical interstices which exist between the individual histological constituents of the epidermis, the latter is traversed by numerous apertures lying more or less closely together. These apertures are those of the sweat and sebaceous glands and hair follicles, and lead into canals containing, and surrounded by, saline liquids. An easy way is thus offered to the current into the deeper epidermic and other tissues of the body. The resistance of any portion of the epidermis depends largely upon the number of such apertures it contains. We can thus understand why Drosdoff found no correlation between the thickness and the conductivity of the integuments at various points of the surface. Even when thoroughly moistened the epidermis becomes a tolerable conductor only where it is very thin.

At any rate the variations in the thickness of the epidermis, in the degree of saturation, and in the number of sweat ducts, &c., it contains, are sufficient to explain why its resistance varies at different points of the body, and at the same points, at different times and in different individuals. These variations are very considerable indeed; sex, age, race, and mode of life have the greatest influence in determining them. Exposed portions of the skin behave differently from those that are covered or protected; the activity, as well as the number of the sweat glands diminishes resistance, as do also frequent bathing or washing, friction or inunction, &c. In certain pathological conditions also the resistance is greatly altered; for instance, in hysterical hæmianæsthesia Vigouroux and Estorc have found that it is greater on the affected side, and that this increase accompanies the phenomenon of ‘transfer’ to the opposite side of the body, though after a few applications of the current these manifestations tend to disappear.

It is necessary to pay careful attention to the great variations in the conductivity of the human body observed under all these circumstances; and I shall illustrate this proposition by giving the results of a few observations which bring into relief both the local and individual differences of resistance. If you place electrodes of exactly the same size, equally moistened with warm water and for an equal period, upon various symmetrical points of the body (the number of cells in circuit and the galvanometer remaining the same), you will find that the strength of the current, estimated in degrees of galvanometric deflection, will vary, as the following instance shows:—

Electrodes on the two temples	40°
,, ,, ,, cheeks	50°
,, ,, sides of neck	35°
,, ,, scapulæ	20°
,, ,, lumbar muscles	5°
,, ,, anterior surface of thighs	3°
,, ,, external surface of thighs	2°
,, ,, popliteal spaces	26°
,, ,, anterior surface of forearm	25°
,, ,, external surface of forearm	22°
,, ,, ,, ,, palms	20°

These phenomena are to be observed on every individual. The differences between the resistances of the same points of the skin in different individuals are still more striking. In ten healthy young men I have found the following deflection on applying the electrodes, with the same number of cells, over the sternum (anode) and right ulnar nerve (kathode):

10° 18° 9° 7° 6° 16° 4° 8°.

In two young girls ten cells, with kathode on neck and anode on sacrum, gave deflections of 33° and 5° respectively. In the latter eighteen cells were necessary to obtain a deflection of 33°.

In two men with lead paralysis, and who both were taking sulphur baths, the following differences of resistance were observed:—

EXPERIMENT I.—*Anode on Sternum, Kathode on Left Deltoid.*

	CASE A (age 44)	CASE B (age 26)
6 cells	31° defl.	4° defl.
4 ,, ...	26° ,,	2° ,,
2 ,, ...	16° ,,	0° ,,

EXPERIMENT II.—*Anode on Sternum, Kathode on Right Radial.*

	CASE A (age 44)	CASE B (age 26)
6 cells	29° defl.	7° defl.
4 ,, ...	24° ,,	3° ,,
2 ,, ...	14° ,,	½° ,,

Such enormous differences are testified by numerous other examples.

The resistance of the same portion of the skin in the same individual, undergoes considerable variations with increasing strength of current, more complete soaking, hyperæmia, &c. This fact is most important in the quantitative estimation of excitability, and can be demonstrated with the greatest ease. Leaving the electrodes *in situ*, we find that the initial galvanometric deflection increases with the duration of the current (the number of cells remaining the same). It increases with every fresh closure, and still more with every reversal, of the current, and finally remains fixed at a much higher number than at the beginning of the experiment. This diminution of resistance is still more striking when we begin with a small number of cells, which is gradually increased, and diminished again to the original number. In the following example the number of cells is increased by fours; at every step the current is made several times and reversed until the needle reaches its final point of rest. The deflections were as follows:—

With 8 cells . . .	0° defl.	With 20 cells . . .	46° defl.
,, 12 ,, . . .	6° ,,	,, 16 ,, . . .	40° ,,
,, 16 ,, . . .	28° ,,	,, 12 ,, . . .	34° ,,
,, 20 ,, . . .	42° ,,	,, 8 ,, . . .	26° ,,
,, 24 ,, . . .	50° ,,	,, 4 ,, . . .	12° ,,

The resistance was thus gradually reduced until four cells gave a considerably larger deflection than twelve cells previously did. This circumstance makes it difficult to perform the gradual 'switching out' of the current, of which you shall hear by-and-by. Among the immediate causes of this diminution of resistance by the action of the current itself some are of a physical order ('cataphoric,' i.e. due to actual transference of liquid into the epidermis), for it is observed on the dead body also; but we must not overlook the physiological effects of the current upon the blood vessels of the skin, which are dilated, those due to the greater quantity of liquids in and about the integuments, and the activity of the sweat glands. The application of a sinapism likewise greatly diminishes the resistance of the skin.

You will often be astonished to see what considerable resistances are offered by the skin of children, and still more by that of old people; so that in the latter you may apply—to the head, for instance—a number of cells which the strongest of young men could not bear. The galvanometer will tell you, however, that this 'tolerance' or 'torpor' of the brain is merely a phenomenon due to a high resistance of the skin. Thus I have been obliged to apply 24 cells (in full working order) to the head of an old man of 70 to obtain the requisite current strength (30°-35° defl.) You will every day be able to make observations of this nature. You must therefore make it an absolute rule to estimate the resistance by means of a few preparatory galvanometric observations before examining or treating any patient.

With reference to the absolute amount of this resistance very variable and illfounded statements have been made. The researches of Jolly and Gärtner, however, have finally decided the point. In contrast to the extravagant and inconsistent estimates of previous writers are the more accurate conclusions of these observers. The resistance of the human body, and therefore, in reality, of the skin, has been variously taken—from different points of view, and usually without any accurate determination of the surface area of the electrodes—as between 1–6,000 or perhaps 5,000 Siemens's units.[1]

Gärtner, on the other hand, and, after him, Jolly, making use of Wheatstone's method, which is alone reliable, ascertained the initial resistance of the skin to be vastly greater than this. From their experiments, performed at various parts of the skin, and upon different individuals, with electrodes of about 12·5 sq. cm. surface, it appears that the resistance nearly always exceeds 100,000, that it ranges usually between 200,000 and 400,000, and that it sometimes attains to 600,000 S.U. On the cheeks and temples it is generally less than 100,000; and what is very remarkable, it is far the least at the palms (30–40,000) and soles (23–32,000) (Jolly). This initial resistance, however, is instantly and rapidly reduced under the action of a moderate, and still more of a powerful, galvanic current; so that with 12 of Stöhrer's cells it is lowered in 5 seconds to $\frac{1}{2}$, in 30 seconds to $\frac{1}{4}$, and by repeated reversals may be brought to $\frac{1}{10}$ or even $\frac{1}{30}$ of its original proportions. In this way a resistance at the outset of 2–400,000 may be brought down to 20–10–7,000 S.U. This diminution of resistance, however, occurs but slightly, or not at all, in the case of the palms and soles, and here we see how it was that the older observers, working, as they did, with powerful currents, ascribed to these parts the greatest measure of resistance.

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[1] Siemens's unit is that which is usually taken for the expression of resistance to the current. It is the measure of the resistance of a column of quicksilver, 1 sq. mm. sectional area and 1 metre in height.

Now Gärtner has established that a similar diminution, but to a less degree, may be effected on the dead body, and that it takes place almost exclusively in the cuticle. It cannot be doubted that the principal agent in the process is the 'cataphoric' action of the current; but Jolly insists, and to my mind with good reason, upon attributing their due share in the phenomenon to the physiological effects, such as the dilatation of the blood vessels, saturation of the tissues, and stimulation of the sweat glands.

These facts, however interesting in themselves, are of secondary importance for our purpose. We are not engaged with currents of infinitesimal proportions and momentary duration; and we have therefore to do, in every instance, with the modified and reduced resistance. We seldom have to apply electricity to the soles or palms, and relatively to the other parts, after the process of reduction, these retain their excessive resistance. For these reasons, the exposition which I have already given remains the most serviceable for practical purposes.

Compared with the effects of the resistance of the skin on the current strength, that of the actual distance which the current has to travel through the body is of small importance. It may be considerable without influencing the strength of the current, which is mainly regulated by the condition of the epidermis at the point of contact of the electrodes.[1] A pregnant illustration of this fact is that when the electrodes are placed on the nape of the neck and the popliteal space respectively, the current is much stronger than when they are both placed on the shoulder blades or lumbar region, though the distance is more than 1 metre in the first instance, less than 12 or 15 centimetres in the latter. The following experiment illustrates these facts.

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[1] According to Jolly, the resistance of the two layers of cuticle is equivalent to about 300 times that of the remaining tissues included when a current is transmitted from one arm to the other.

Healthy man, middle-aged; two electrodes (A, B) of the 'medium' size are placed upon different points; current of 10 cells allowed to flow until the needle comes to rest; then a reversal is made and both deflections noted. Resistance 150.

Position of Electrodes	Distance between them in Centimetres	First Deflection	Second Deflection
A Nape of the neck . . . B Popliteal region . . .	100	19°	24°
A Right lumbar region . . B Left " " . .	10	10°	15°
A Sternum . . . . . B Forearm (inner aspect) . .	50	2°	8°
A Sternum . . . . . B Deltoid	21	11°	15°
A, B Forearm (inner aspect) .	5	½°	2°

By varying in other ways the relative position of the electrodes in such an experiment we obtain clear proof that it is not their distance from one another which determines the current strength.

It is, therefore, of all the resistances in circuit, that of the epidermis which exercises the chief influence upon the strength of the current. Since the *length* of this conductor (i.e. the thickness of the epidermis) varies within comparatively narrow limits, it is its *diameter* which finally regulates the strength of current through the body obtainable from a given electromotive force. This diameter can be modified at will, and is nothing more than the *extent of the surfaces* of the skin through which the current penetrates into and emerges from the body. In other words, it is the *size of the electrodes* upon which mainly depends the current strength; the nature and extent of the tissues under the epidermic layer is of relatively small consequence.

The practical consequences of these propositions are of the highest importance. The electrodes must be the larger the stronger the current required (the limitations to this dictum will be considered further on when we speak of the density). This can easily be shown on the galvanometer; electrodes of various sizes applied to the same points, with the same number of cells in circuit, gave the following current strengths:—

'Smallest' electrodes		4°
'Small'	,,	13°
'Medium'	,,	20°
'Large'	,,	30°

It is obvious that the size of the electrodes cannot be increased beyond certain limits. In order to avoid the necessity of using large metallic plates or carbon electrodes, pads of moistened blotting-paper have been applied to the skin, upon which an ordinary electrode was placed. But this method is very inconvenient, and experiments I have made with reference to the conduction of the current through these pads have convinced me that there are no advantages to be gained thereby.

4. The current in a closed circuit traverses not only the external portion of it, but the cell itself, in which the metals and liquids contained offer a certain resistance, according to their nature and disposition. Such a resistance is known as the 'internal' resistance, whereas the resistance of the remainder of the circuit is designated as 'the external resistance.' Both together form the 'total' resistance, and the same laws apply to each. Hence the internal resistance increases with the increasing length and diminishes with the increasing diameter of the conducting media; in other words, the farther the two metals are from one another and the longer the path in the liquid, the greater the resistance (and the weaker the current); the larger the metallic surfaces, or the deeper their immersion in the liquid, the larger the diameter of the path in the liquid and the smaller the resistance (the stronger the current). Hence the internal resistance is also of importance, and the formula we have been considering previously becomes $C = \frac{E}{R+r}$, where R represents the internal and r the external resistance.

We may therefore modify the current strength by altering one of three factors—the electromotive force, the internal and the external resistance. In electrotherapeutics the given external resistance we have to deal with is that of the part of the human body included between the electrodes. Hence in order to alter the current strength in the circuit we must introduce changes in one of the other two factors, either (1) adding to or subtracting from the electromotive force or (2) diminishing or increasing the internal resistance. A simple consideration will show you that we must under definite circumstances do either the one or the other, and that both do not suit every case.

In electrotherapeutical applications we have to work under two very different conditions. When we send the current through the skin for medical purposes the circuit contains the human body, which presents an enormous resistance—a resistance much greater than that of the battery itself. The external resistance is here, therefore, much more considerable than the internal. When in surgery, on the other hand, we use the galvanocautery it is a metallic wire, a good conductor, which forms the external part of the circuit; the resistance of the latter is much less than the internal resistance of the battery. You will readily perceive the principle implied by this illustration, and see how it is that in the first case changes in the internal resistance remain without any appreciable effect upon the current strength, whilst in the second such changes have necessarily a great influence and are the main condition to determine that strength.

It can be readily shown with regard to the first case that if we wish, for example, to increase the current strength, we cannot do this by diminishing the internal resistance by the enlargement or deeper immersion of the metals or their closer approximation to one another, &c., but only by the addition of new electromotive force, i.e. by an *increase in the number of elements*.

Let us assume that in the percutaneous application of the current in a given case the internal resistance is 8, the external 200 units, then—

$$\text{for one element } C = \frac{E}{R+r} = \frac{1}{8+200} = \frac{1}{208}$$

$$\text{for two elements } C=\frac{2E}{2R+r}=\frac{2}{16+200}=\frac{2}{216}=\frac{1}{108}$$

$$\text{for four elements } C=\frac{4E}{4R+r}=\frac{4}{32+200}=\frac{4}{232}=\frac{1}{58}.$$

In other words, we have almost doubled the current strength by doubling the number of elements, and so in proportion. On the other hand, if we use larger cells we shall diminish the internal resistance. Taking the same numbers as before, we have for an element twice as large

$$C=\frac{E}{\frac{R}{2}+r}=\frac{1}{4+200}=\frac{1}{204};$$

and so the current strength practically has not been increased.

Let us see now what happens when the internal resistance is large as compared with the external, a condition that obtains in galvanocaustics. Let us, for simplicity's sake, assume R to be equal to 200 and r to 8; we shall have

$$\text{for one cell } C=\frac{E}{R+r}=\frac{1}{200+8}=\frac{1}{208}$$

$$\text{for one cell twice as large } C=\frac{E}{\frac{R}{2}+r}=\frac{1}{100+8}=\frac{1}{108}$$

$$\text{for one cell four times as large } C=\frac{E}{\frac{R}{2}+r}=\frac{1}{50+8}=\frac{1}{58}.$$

Thus you see that here the current is increased by increasing the size of the elements, but not by multiplying their number.

Hence we conclude that in medical practice, in the percutaneous application of the current to the human body, the current strength is increased by multiplying the number of elements, but not by enlarging the individual cells. It follows that the large elements which were formerly employed are unnecessary. We may use as small ones as we like, making their size depend merely upon conditions of a technical and practical nature.

We have been just now discussing the regulation of the current strength through modification in the battery power; you will, however, remember that it may likewise be effected by means of a rheostat included in the main or in a derived circuit.

5. A clear conception of the *density* of the current is of the utmost importance towards an understanding of the effects of the current and its rational application in practice.

The experiments of physiologists teach us that an appreciable exciting effect upon the peripheral and central nervous system occurs only when the current passing through those structures has a certain 'density.' It is at least probable that the same condition obtains also for the therapeutic effects of the current, that at least a considerable portion of them are only produced when the diseased part is brought under the influence of a current of the requisite density.

By the term density of the current we understand the relation of the strength of the current to the transverse section of the conductor through which it passes. The strength of the current remaining the same, its density is inversely proportional to the transverse section of the conductor, or $D = \frac{C}{S}$. This relation will be understood most readily, I believe, if you consider the subject under a material image, and suppose the electrical current to be composed of a large number of individual parallel threads. The greater the number of threads composing a current, the greater is the strength of the current; the greater the number of threads which are compressed into a unit of the transverse section, the greater is the density of the current. The more of these threads that go to form a current the greater its strength; the more are packed together into a unit of area the greater its density. If you imagine a current, for example, of 1,000 threads carried in one case through a metallic conductor having 1 sq. cm. transverse section, in another case through one which has an area of 2 sq. cm., the 1,000 threads in the second case will be dispersed over twice as great an area as in the former; the current therefore possesses but half the density in the latter instance, while it has the same strength in both cases. Fig. 9 may serve as a diagrammatic representation of these facts. The current is comparable to a girl's hair, which may be gathered up into a narrow tress or allowed to flow loosely without changing the number of its constituent parts.

It now appears that appreciable physiological and therapeutical effects do not occur until the number of threads of current, passing through the transverse section of a given portion of animal tissues, exceeds a certain limit. It is therefore important to obtain a clear idea of these conditions and to describe fully the methods by which it is possible to bring any desired part of the body under the influence of a current of a certain density.

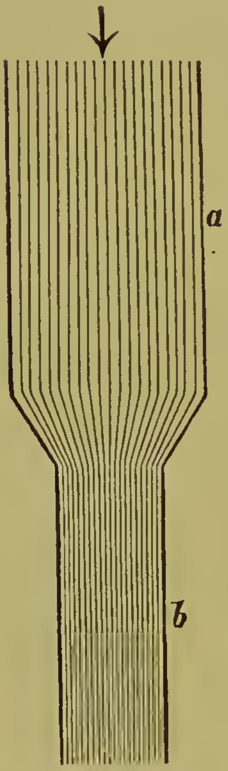

FIG. 9.—Diagrammatic representation of varying density of the current, its strength remaining the same; the same number of threads of current in part *b* of the conductor compressed into half the area of part *a*: the density in *b* is therefore twice as great as in *a*.

For this purpose you must, first of all, form an idea of what happens to the current and its threads when we introduce them into the body in the ordinary manner—i.e. from any two points on the surface of the body, by means of electrodes which are applied to those parts. A number of threads of current, corresponding to its strength, here enter the body; and they are dispersed in all directions[1] according to Ohm's laws. All the threads of the current enter through the area of the electrodes, and are then spread over the much larger area of the body or part of the body included between them. The greatest density, therefore, must always be present immediately beneath the electrodes; when these are of equal size, the density of the current must be equal at both electrodes (see fig. 10); if the electrodes are of different sizes, the greatest density must always exist under the smaller one, because the same number of threads of the current are here compressed into a smaller space (see fig. 11).

In the interior of the body the greatest current strength will be found in the straight line connecting the electrodes, i.e. in the line of least resistance according to proposition 3; the largest number of threads of the current will be here close together, and therefore the relatively greatest current density will also be found in this situation. You must not imagine,

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[1] These 'threads of current' (*Stromfäden*) are really *derived* currents, when not in the straight line connecting the two electrodes.

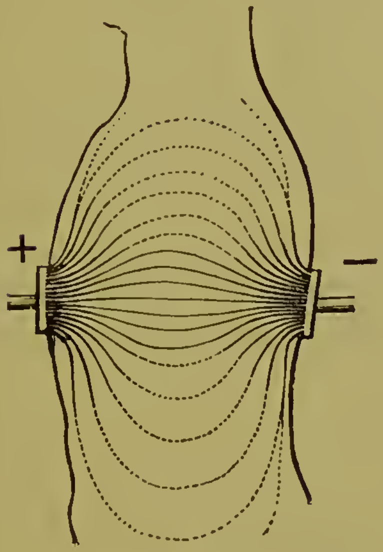

FIG. 10.—Diagrammatic representation of the distribution and density of the current with two electrodes of equal size : the density beneath them is equal.

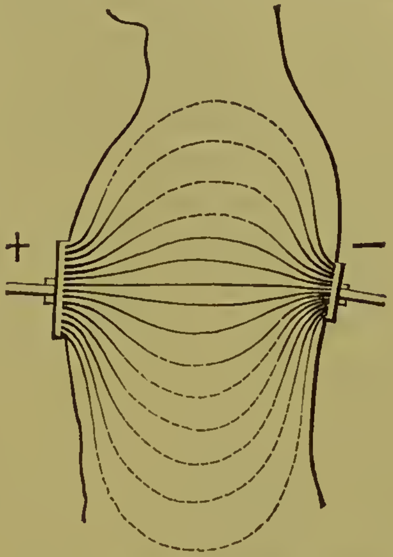

FIG. 11.—Diagrammatic representation of the density of the current with electrodes of different sizes, the A twice as large as the K ; the density beneath the K is twice as great as beneath the A.

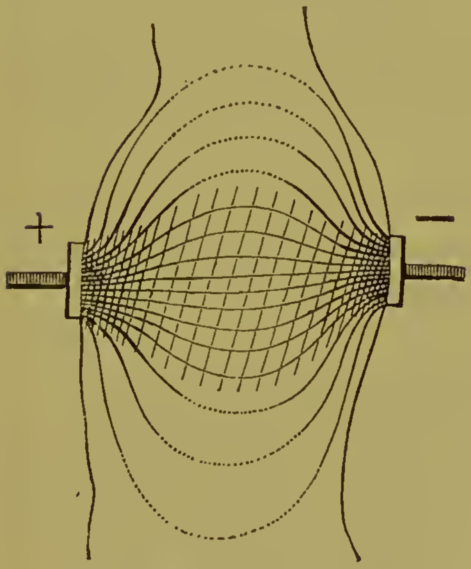

FIG. 12.—Diagrammatic representation of the density of the current in its transverse passage through the body. The ineffective threads of current are dotted. The approximate zone of greatest density is shaded.

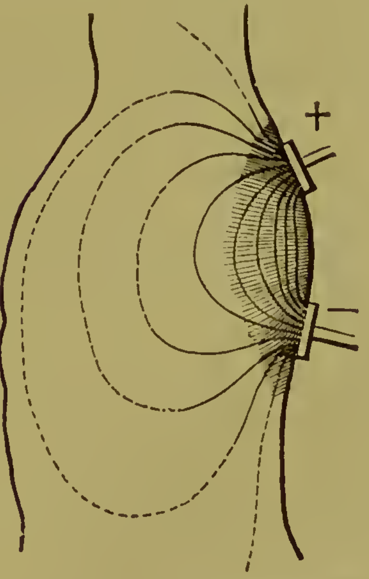

FIG. 13.—Diagrammatic representation of the density of the current upon application of the electrodes to the same surface, close to one another. Ineffective threads of current dotted. Zone of greatest density shaded.

however, that this density can ever be considerable, since, on account of the great area of the body and the approximately uniform conductivity of its parts, the density must diminish markedly very close to the electrodes. However, under specially favourable conditions—such as the transverse conduction of the current through the head with tolerably large electrodes, or its transverse conduction through an extremity—a fairly considerable current density may be secured even in the depths of the tissues. According to the relative position of the electrodes, the zone of relatively greatest density of the current between the electrodes will vary somewhat in shape; in transverse passage of the current through the body or individual parts of it, this zone will have the shape of an expanding cylinder, extending from one electrode to the other, as in fig. 12; if, on the other hand, the electrodes are placed near one another upon the surface of the body, it will approximate to the shape of a section of a sphere or cylinder, the base of which corresponds to the surface of the body, as represented in fig. 13. In both figures the shading represents the zone of greatest density, the latter increasing as the zone narrows towards the two extremities. Those parts of the body situated outside of this zone, although they necessarily receive a certain number of threads of current (determined by Ohm's laws), nevertheless present such a slight density of current that they may be left entirely out of consideration.

Gentlemen, you must become thoroughly impressed by those considerations, think them over, and accustom yourselves to illustrate by means of diagrams the various instances in which the phenomena may occur; for therein lies the very quintessence of electrotherapeutical technique. Our object almost always is to localise a current of a certain density in definite parts of the body, and this can be done only by having a clear idea of the facts just developed with regard to the strength and to the density of a current. Upon this depends exclusively the choice of the electrodes and of their points of application for each of our various purposes. Allow me to illustrate this by a few important examples.

A. If you wish to localise a current of a given strength with a certain density in one definite point, not far removed from the surface, two electrodes of different sizes are employed, the smaller one being placed as near as possible to the point in question, whilst the larger one, which you choose as large as possible, lies at a considerable distance; the end desired will be attained the more certainly the greater the difference between the sizes of the electrodes. You must of course remember that if one is very small, the requisite current strength will have to be secured by an increase in the number of elements, as the smaller surface of the electrode causes a considerable increase in the resistance. Such is the method we employ daily in the electrical examination of individual nerves and branches of nerves, in the local excitation of these organs or of the motor muscular points for therapeutical purposes, &c.

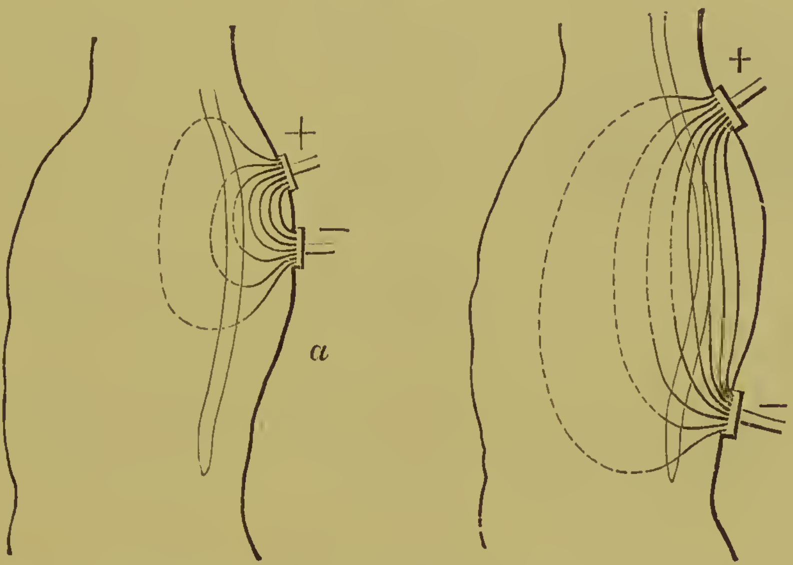

FIG. 14.—Diagrammatic representation of the distribution and density of the threads of current with regard to their entrance deeply into the tissues (in this instance into the spinal cord). *a*, when the electrodes are in close proximity; *b*, when far removed from one another.

B. If you wish to localise the current in larger parts near the surface, choose two moderately large electrodes of equal size and apply them relatively near to one another upon the part of the body in question, so that the latter falls within the spherical segment of relatively greatest density, as shown diagrammatically in fig. 13. This method should be adopted, for example, if your purpose is an energetic electrisation of the deltoid, the biceps, the glutæus, the vastus internus, an enlarged joint, &c.

C. If you intend to localise the current in parts situated deeply, you may use one of two methods. According to the first the electrodes should be as large as possible and be placed upon the part in question at the greatest possible distance from one another; for the closer the electrodes are to one another the greater will be the difference between the length of those threads of current which pass superficially and those which pass deeply from one electrode to the other, and thus the greater the number which will remain near the surface. If the electrodes are widely separated this difference will become less, and comparatively more threads of current will pass into the deeper parts, as is shown in fig. 14. This method is especially employed in the treatment of the spinal cord, which is relatively far removed from the surface; the rule here is 'large electrodes, widely separated.'

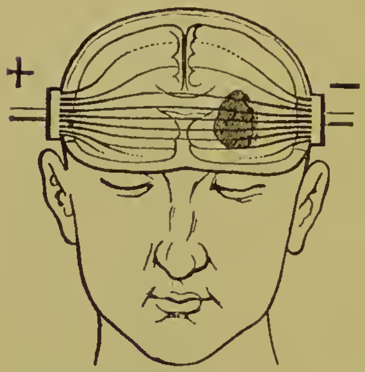

Fig. 15.—Diagrammatic representation of the best method of application of the electrodes in order to bring a lesion, situated deeply in the left cerebral hemisphere, into the field of the most dense and effective threads of current.

Or you may choose two electrodes of equal size and apply them in such a manner that the part in question is situated, as far as possible, in the straight line connecting them (shown in fig. 12 to be the cylinder diagrammatically represented therein). This method is especially adapted for treatment of deep-seated diseases of the brain (as is shown clearly in the adjoining diagram), but may also be employed to influence circumscribed foci of disease in the spinal cord, for the treatment of morbid processes situated deeply in the viscera, &c.

One of these three methods of application will suffice under any circumstances to give you the desired results. But you must be always quite clear about the one you are to choose and the reasons why you choose it.

It may be noticed here that these conditions governing the distribution of electrical currents in the human body hold good chiefly, as it seems, for the galvanic current, at least so far as the action upon deeper parts is concerned. As Helmholtz has shown, the faradic current appears to act somewhat differently in this respect, and does not enter deeply with the same rapidity and readiness as the galvanic current. This fact may explain various electrotherapeutical observations, such as the fact that deeply situated nerves and muscles are much more readily excited by the galvanic than by the faradic current, that the latter does not produce the expected effect upon the spinal cord and brain, the viscera, &c. This is certainly a point of practical importance.

In conclusion I will refer briefly to two of the physical effects of the current, which are, perhaps, of no slight significance in electrotherapeutics. At any rate we have constantly been compelled to invoke their aid in the framing of hypotheses in explanation of the curative effects of the current.

The first is the *electrolytic* action of electrical currents. You are acquainted with all the details of this action, and I need remind you merely that, in the passage of the current through certain compound conductors (electrolytes), these are decomposed into their component parts, the latter being given off at the two poles—the so called electronegative elements (oxygen, iodine, chlorine, &c.) and the acids at the anode, the electro-positive elements (hydrogen, potassium, sodium, copper, &c.), the alkalies and bases, at the kathode. Thus water is decomposed, hydrogen being given off at the negative, oxygen at the positive pole ; chloride of sodium and iodide of potassium likewise yield soda at the kathode, chlorine and iodine at the anode.

Exactly similar phenomena occur also in animal fluids and tissues; as Dubois-Reymond, Hermann, and others have shown, the electrolytic processes occur wherever a current passes from another conductor into an electrolyte, where two electrolytes are in apposition, and also in the interior of more solid masses which are permeated by an electrolyte and through which a current is flowing. The animal organism, when penetrated by an electrical current, presents such a condition ; electrolytic processes may therefore develope within it.

Decomposable fluids, however, or electrolytes, are present also in the elements which produce galvanic currents, and these are subject to electrolysis during the closure of the circuit. Ions are thus set free in a gaseous or solid form at both metal plates ; a new electromotive force is thus generated in the battery, opposed to and enfeebling the original main current. This process is called polarisation of the battery. It is the cause of the inconstancy of the ordinary simple batteries; in other words, their electromotive force gradually diminishes during the period of closure. You all know of the attempts which have been made to prevent polarisation and produce so called constant elements. Their object has been completely attained in the elements of Daniell, Bunsen, Leclanché, and others. These are matters of the greatest interest from a physical point of view and for certain technical purposes.

Much has been said concerning the necessity of using such elements in electrotherapeutics; but let me repeat that for our purposes really constant elements are quite unnecessary, since, on the one hand, even inconstant batteries will suffice during the short period of the application of the current; and, on the other hand, it is a well-ascertained fact that even with the most constant elements we can never succeed in producing anything like a uniformly constant current in the human body.

This does not mean, however, that certain constant elements, having so many advantages arising from their durability, uniformity, and facility of manipulation, do not deserve the preference. Only it is immaterial for ordinary therapeutical purposes whether the elements possess a perfect constancy or not.

The various forms of current are endowed with very different degrees of electrolytic activity; by far the greatest is possessed by the galvanic current, much less by the magneto-electric induction current, and still less by the volta-electric induction or faradic current. These facts have been connected with the great difference of duration that obtains amongst the various forms of electric current; and I may mention that some have ascribed their therapeutical effects to the electrolytic action of each. But I shall revert to this subject later.

The other physical effect to which I wish to call attention is the so called mechanical or *cataphoric* action of the electrical current. It is possibly of great importance in therapeutics and depends upon the general fact that, during the passage of a current through an electrolyte, contained in porous bodies (such as clay, baked or not, animal and vegetable tissues, &c.), fluid is moved from the anode to the kathode, i.e. in the direction of the current. The amount of fluid conveyed in the porous body, in a unit of time, is so much larger the stronger the current and the less the conducting power of the fluid. Firm particles, suspended in the fluid, are said to move in the opposite direction to the fluid itself. It is evident that the animal tissues are constructed in such a manner as to favour the production of these cataphoric effects.

THIRD SECTION.

PHYSIOLOGICAL INTRODUCTION.

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LECTURE V.

Action of Electric Currents upon the Healthy Living Body—Electrophysiology of the Motor Nerves and Muscles—Excitation—Pflüger's Law of Contraction—Polar Effects—Unipolar Method of Investigation—Polar Law of Contraction and its Degrees—Faradic and Galvanic Reactions of the Muscles—Electrotonic Phenomena—Electrotonus in the Living Man—Modifying and Refreshing Effects.

I NOW pass to the physiological effects of electricity upon the living body. We shall first determine in what manner electric currents influence the individual organs of the human body under physiological conditions, and what consequences follow their application to these parts. In this way important deductions may be drawn from all the data, with regard to diagnosis, as well as to the treatment of morbid conditions. Concerning the physiological effects of currents there is a considerable accumulation of facts, for modern physiologists have expended upon this subject more time and energy than upon the solution of any other problems; and if the clear and exact knowledge of the effects of an agent is a necessary condition for its rational application in therapeutics, we find ourselves in a peculiarly satisfactory position with reference to electricity. The electrophysiology of the nervous system and of the muscles teaches us a large number of most important and interesting facts; and we possess concerning it a depth and exactness of knowledge scarcely excelled in any other branch of physiology.

And yet a closer investigation, made in the light of our special practical wants, soon teaches us how very incomplete physiological science still is, and how many important problems remain unsolved. Electrophysiology does not yet afford a sufficiently secure basis for any bold construction of therapeutical hypotheses. It may even appear that those effects of the current which physiology has attentively studied are not those upon which curative applications must be founded.

The influence of electric currents on the *motor nerves and the muscles* has been most intimately studied. This subject is of importance to us, because it forms a safe starting point for electrodiagnosis, and also because the diseases of the motor system form the chief object of our therapeutics.

I turn first to the motor nerves, paying special attention to the *exciting* (or stimulating) effects of electrical currents upon them.

It is a fact which can be demonstrated at any moment that the motor nerves of man and the vertebrates (either laid bare or left *in situ*) can be excited by the application of electrical currents (faradic or galvanic), and that this excitation is manifested by a muscular contraction in the muscle supplied by the excited nerve.

Electric excitation has been reduced to a law by Dubois-Reymond. 'It is not the absolute degree of the density of the current at any certain moment which acts as an excitant to the motor nerves, but only the change in its degree from one moment to another; i.e. it is only variations in the density which excite, and their action is the more intense the greater their amplitude in a unit of time; or their amplitude being equal, the more rapidly they occur; most intense, therefore, upon sudden closure and opening of the current.'

From this it follows that, as a rule, a perfectly constant galvanic current does not produce any excitation during its flow; furthermore, that a very gradual diminution or increase of the current remains without any visible exciting effect, even for currents of great strength; and finally, that simple variations of density, the circuit remaining closed, may act as a stimulant, provided that such variations occur in sufficient amount and with a certain rapidity.

Hence follows, also, the powerful exciting effect of faradic currents upon the motor nerves; they are made up of currents of very short and abrupt course, and thus set up in the nerve very considerable and very sudden variations of density. If you allow induction shocks to act upon a motor nerve, each shock will be followed by a short muscular contraction, corresponding to the strength of the induction current. The contractions are more energetic at the opening, than at the closing, current of the secondary coil. If you allow a series of such shocks to act upon a nerve, an identical series of muscular contractions will follow; if the succession of these excitations attains a certain rapidity, the individual contractions will run into one another and be 'summated' into a single permanent or tetanic contraction. It is unnecessary to enter into the details of the excitant effect of faradic currents, which have as yet scarcely been investigated by physiologists; it will suffice to mention that each individual induction current acts usually as a mere closure shock; the opening excitation appears to be insufficient to produce any noticeable effect.

The exciting effects of the galvanic current on the motor nerves are easier to understand, and have been much more thoroughly studied. Every sufficiently ample variation in the density of a galvanic current, conveyed to a nerve, produces an excitation of the nerve, and thereby a muscular contraction; the latter most marked in the case of variations of density arising from makes and breaks of the circuit. It was early recognised that the excitant effects produced by making and breaking currents of various strengths, and also by changing the direction of the current in the nerve, present certain differences, and much time and labour has been devoted to discovering the relations between these differences and the respective stimuli. Pflüger was the first to give an accurate and scientific formula for these phenomena (Pflüger's law of contractions). We understand by this term the appearance, in a definite order, of muscular contractions produced by the closure and opening, through the nerve, of galvanic currents of varying strength and direction (ascending or descending). This law, however, applies to the exposed and exsected nerve only, and is stated as follows:—

With *weak currents*, in either direction, contraction occurs on closure alone, but none is produced on opening; the contraction is somewhat stronger on closure of the ascending, than of the descending, current.

With *moderate currents*, contractions occur on opening and closing in both directions; but the former are always weaker than the latter.

With *very strong currents* (such as are never employed on human beings), contraction occurs only on opening, none on closure of the ascending current; only on closure, none on opening of the descending current.

By a series of most ingenious experiments, the results of which have been confirmed and expanded by Bezold and others, Pflüger was able to reduce these phases of his law of contractions to facts which are both well established scientifically and most important for us. The chief of these is that the exciting effect of the galvanic current occurs only at the poles and starts from them; i.e. the excitation on closure occurs at the kathode only, on opening at the anode only. Pflüger also found that the exciting action of the kathode is greater than that of the anode, and that the closure excitation of a given current is greater than its opening excitation. It was further found that the more central portion of a motor nerve is more excitable than the peripheral portion; and, finally, that with very strong currents considerable resistance to the propagation of the excitatory wave occurs at both poles, and increases with the strength and with the period of closure of the current. Pflüger's law can be explained on these data in the simplest manner. With *weak* currents contraction occurs only on closure in both directions of the current, because contraction on closure is the stronger and appears first; contraction on closure of the ascending current appears somewhat earlier, because the central part of the nerve on which the kathode is placed is somewhat more excitable. When the current is *moderate* the closure contraction, in both directions of the current, is stronger than the opening contraction, on account of the predominant exciting effect of the kathode. When the current is *very strong*, the resistance to the conduction of the nerve impulse, which is developed at the poles and disappears but slowly, inhibits the propagation of the closure excitation when the current is ascending, and the propagation of the opening excitation to the muscle when the current is descending, and thus produces this peculiar phase of the law of contractions.

You must especially bear in mind the fact, arising from the considerations just presented to you, that these phenomena of muscular contraction depend only upon the different effects of the two poles; and that the closure contraction (CC) is the effect of the kathode only, the opening contraction (OC) the effect of the anode only; that the closure excitation (kathodic action) is considerably greater than the opening excitation (anodic action). We shall find that these statements apply to the human subject also.

This is not the place to discuss the very plausible view lately put forward (P. Grützner, Tigerstedt, Biedermann, Hering), and according to which there is in general no such thing as an opening excitation, but what is regarded as such is in reality either due to the occurrence of secondary polarisation currents upon the cessation of the primary polarising current, and opposed to it in direction, or else it is determined by the production of a normal nerve current in the nerves acted upon. This theory, at any rate, is competent to explain the manifestations of the law of contractions in a satisfactory manner, but physiologists have yet to satisfy themselves of its truth. In electrical diagnosis and treatment it is of secondary importance.

You will observe, that when the current is strong, its closure is not followed by a simple short contraction, but often by a long-drawn tonic or tetanic contraction, which gradually subsides (closure tetanus, CT). Physiologists have taken much trouble to explain this phenomenon, which is opposed to the law of Dubois-Reymond and compels us to assume that the motor nerve is excited also by a current flowing uniformly through it. It is, indeed, assumed that even weak descending currents have a tetanising influence; but the explanation of this fact is not clear, and if I mention it, it is only because we are constantly in a position to affirm its occurrence in man.

A similar question is that, much discussed by physiologists, of the opening tetanus—that is, of an opening contraction which assumes the shape of a tonic persistent spasm. This phenomenon is not easily observed in quite fresh and normal nerves, but only in such as have been already modified or the excitability of which is much increased. An explanation of it is not difficult to derive from Pflüger's law of electrotonus. Unlike closure tetanus, the opening tetanus is very rarely observed in man, and apparently under pathological conditions only.

Pflüger's laws also explain another phenomenon which was at first known under the name of *voltaic alternatives*. When the circuit has been closed some time and the current has flowed in one direction, the excitability of the nerve is increased to opening excitations by currents in the same direction, to closure in the opposite; repeated changes in the direction of the current (which in electrotherapeutics we term *current reversals*), therefore, produce a considerable increase in the amount of contraction. This cannot by any means be explained by the diminution in the resistance of the tissues, which is undoubtedly brought about by the reversals, but rather by the summation of the exciting effect of the anode (disappearance of anelectrotonus) and of the kathode (development of katelectrotonus) at one and the same part of the nerve, where both effects alternate at each change of polarity.

Furthermore, Rumpf has recently shown, by a series of physiological experiments, that, in a motor nerve which is still connected with the central organ, the opening contraction of the ascending current, after long flow and with considerable strength, occurs considerably later than in one which is separated from the central organ. This we shall observe occasionally under pathological conditions. Biedermann has, however, disputed Rumpf's assertion.

Valentin (1863) had already stated that the only constant reaction of the normal living nerve was produced by the closure of a current in either direction.

I have to add further that motor nerves are absolutely non-excitable to a strictly transverse passage of the current, whether faradic or galvanic, and also to very short (under 0·0015 second) galvanic currents, a peculiarity, however, which is much more marked in muscles.

The practical physician has not to do with the discovery of physiological facts and their reduction to laws; he has to apply them to his art, and for him the question is whether the law of contractions can be demonstrated upon the motor nerves of the living, healthy, and whole human body in such a way, and with such a completeness, that it may serve as a starting point for such applications as, for instance, the diagnosis of nerve lesions.

Experience shows that such a proof can be obtained with the utmost certainty, though the difficulties in the way of a satisfactory result are great, at least from a purely physiological point of view; but the latter does not concern us, and experiments for proving the law of contractions in the living man cannot be compared in exactitude with the experiments of the laboratory. We cannot expose the nerve isolated to a great length and place it upon the electrodes; we have to deal, on the contrary, with nerves which are surrounded with more or less thick layers of well-conducting tissues, and which are permeated by a large number of the threads of current diffusion. We cannot, therefore, possibly maintain any uniform current density in the nerve. The greatest density of the current will always

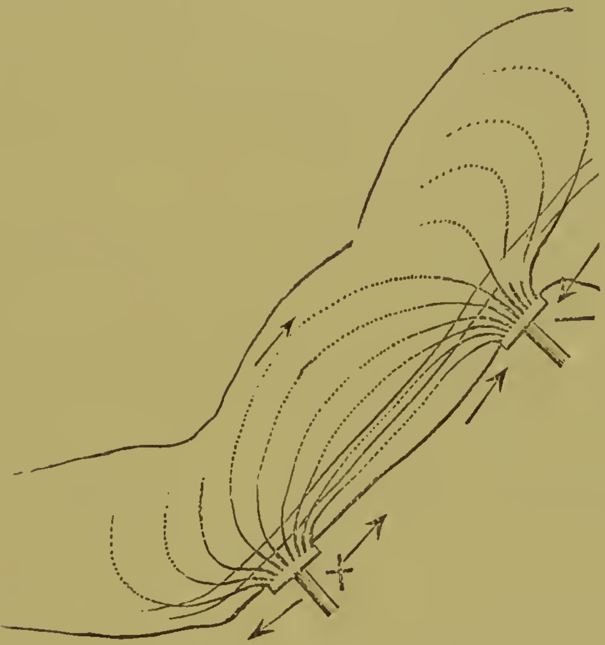

Fig. 16.—Diagrammatic representation of the area of current diffusion in the ordinary percutaneous application of both electrodes to a nerve (ulnar nerve in the arm). The threads of current in the region beyond the zone of the effectual current density are dotted. There are four different directions of the current in the nerve.

be found immediately beneath the electrodes; even in the intrapolar portions of the nerves the density will soon become so slight, if the electrodes are not closely approximated, that a part of the nerve may be regarded as not traversed by the current; and it will be especially impossible to maintain a definite, single direction of the current in the living nerve, surrounded as it is by soft parts. A glance at the above diagram (fig. 16), which embodies a fact, first promulgated by Helmholtz and afterwards worked out by Filehne, will show that in ordinary percutaneous application not less than three, perhaps even four efficient directions of the current must be present in such a nerve. In the neighbourhood of each pole there occur two tracts permeated by an ascending and by a descending current respectively.

Thus it is impossible to institute a strictly physiological experimentation on the living man; more especially the direction of the current, which has erroneously been considered of so great importance, must be excluded from all account; we must strive to find the law of contractions of the living motor nerve within the body without reference to it.[1] We have seen, however, that all the phenomena of the law of contractions depend solely upon polar effects; the first two phases of the law, moreover, show that for them at least the direction of the current is of no consequence, since it does not interfere with the production of the polar effects.

Indeed, there is no doubt that we may, on physiological principles, simplify our task and reduce it to the testing of the pure polar effects on human nerves. We must find whether we can demonstrate these; whether they occur according to a definite law, and appear with regularity under increasing strengths of current.

This problem is solved without much difficulty. If but one pole is brought into the immediate vicinity of the nerve to be tested, and the other is removed as far as possible, the density of the current under the first pole will be comparatively so great that its action will be brought into play almost exclusively. This action may thus be examined separately on closure and opening, and with any direction of the current.

This simple and obvious method was first introduced into electrotherapeutics by Baierlacher. He established the law of contractions by experiments made on the peroneal and ulnar nerves, but he did not deduce any practical consequences from the facts he observed. Brenner, on the other hand, deserves the credit of having systematically studied the method and applied it to man in its full development. Thus was derived the so called polar method of investigation in diagnosis, from which also Brenner obtained a polar method of therapeutics.

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[1] In two works which he has lately published, Stricker has adduced the results of many physiological experiments undertaken with the view of establishing the fact that the law of contractions has no reference to the direction of the current. We must leave it to physiologists to decide whether these experiments are conclusive.

But this method offers also certain difficulties and peculiarities, which one must know and keep before one's eyes in order to obtain results of any value. Filehne, following up the researches of Rob. Schultze, has considerably facilitated the comprehension of the conditions obtaining here, and removed the difficulties which appeared to stand in the way of a reconciliation between the physiological and polar law of contractions.

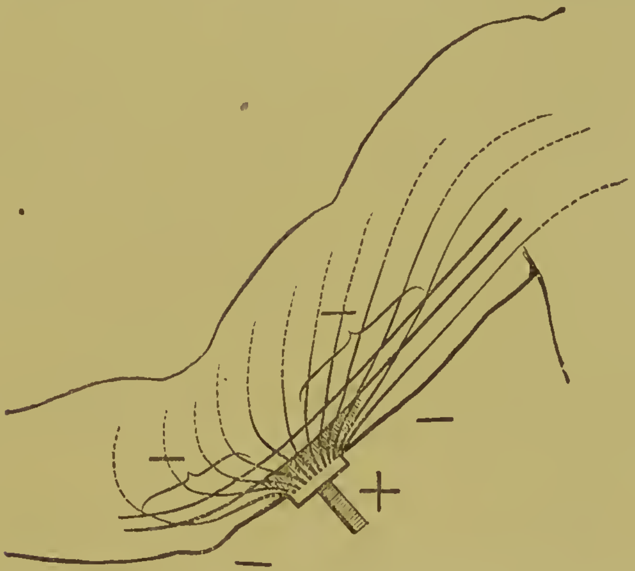

FIG. 17.—Diagrammatic representation of the primary and secondary (virtual) polar action, with the unipolar application of the electrode to a nerve trunk.

We can by no means produce an entirely isolated action of the poles in a nerve; if the current enters a nerve at any point (that is, if there is an anode at any part of the nerve) it must make its exit at some other, perhaps at various places (i.e. it must have a kathode somewhere). It will depend solely upon the density of the current of exit in how far the action of this second pole or virtual electrode comes into play. In fact, a glance at fig. 17, which gives a diagrammatic representation of the phenomena, will show that an isolated pole placed upon a nerve cannot have only one, but must have two opposite poles in its immediate neighbourhood. If the current enters through the anode with a certain density, the derived currents will expand along both directions of the nerve with diminishing density; the kathode may be regarded as present at the point at which the density has become so slight that the current is ineffective. Every anode is therefore placed between two kathodes of much less density, and the converse occurs when the isolated kathode is applied to the nerve. We must, therefore, in this method of application, expect to find, under these circumstances, the action of the opposite pole added to the action of the pole applied directly, though very much enfeebled; and this is what really happens, as I have just told you. We obtain, in addition to the closure effect of the kathode, a weak opening effect, due to the virtual anode; and, in addition to the opening effect of the anode, a closure effect of the virtual kathode. The more or less prominent manifestation of the secondary effect will depend solely upon the peculiarities of the anatomical relations and upon the density of the current in the nerve to which they give rise; indeed, we see that this secondary effect varies in prominence from nerve to nerve, but, as we have to compare reactions of similar nerves under varying conditions, this fact offers no practical difficulty.

Now, the polar method of examination consists in that one electrode, termed 'exciting,' is brought in as close approximation as possible to the nerve to be examined (e.g. fixed over the facial, ulnar, &c., nerve), and then connected as desired with the anode or kathode of the battery, so as to test the effect of either on closure and opening of the current. The other or 'indifferent' electrode is placed on some remote part of the body (sternum, spine, epigastrium, &c.) It is best to accustom oneself always to use the indifferent electrode in the same position on the body. I choose the sternum exclusively, since the electrode can most readily be applied there by the person examined.

The necessary closures and openings of the circuit are best made by means of the metallic commutator. When the kathode lies over the nerve and the circuit is closed, we say that we make a kathodic closure (KC). If now we open the circuit we make a kathodic opening (KO); likewise we speak of anodic closures (AC) and anodic openings (AO). Abbreviations such as those given here will be found a great convenience in practice and have been universally adopted.

It is best to begin (with a low current strength) by examining KC by, say, three closures, and at the same time observing KO; AC and AO are then examined in the same manner. To secure the opening contraction it is advisable to keep the current closed for a little while, as this, you have already heard, increases the excitability to the opening stimulus. With increasing current strengths you then examine at what strength the several contractions and tetanus are obtained, and can then arrange them in a formula for the sake of clearness, in which the various degrees of contraction are represented as C, C′, C″, or C, CC, CCC, &c., according to the strength of the contraction. In making these examinations you make it a rule to employ the greatest uniformity and regularity of method, because in this way only can you arrive at results which may be compared with one another, and can eliminate to a certain extent the numerous sources of error to which such investigations in the human subject are necessarily exposed.

With this method you will easily arrive at the conclusion that in most motor nerves of man the concordance of Brenner's proposition with physiological facts is complete, and that the kathode excites chiefly on closure, the anode chiefly on opening; that in consequence the excitation is propagated from the kathode at closure and from the anode at opening. You will further find that the excitant effect of the kathode is notably greater than that of the anode. The resulting contractions are short, vigorous, and very rapid, provided they do not pass into a condition of tonic spasm.

From this it follows that the earliest contraction produced by excitation of a motor nerve is the KCC, and that the subsequent manifestations can be evoked only by increasing the current strength. Hence the different stages in the law of contractions can be deduced without difficulty. Let us take, for example, the ulnar nerve, which is easily excited. On submitting it to the test we shall find, let us say, that 8 cells are required to produce the first KCC, and that with this number there is no response to KO, AC, and AO. Now with 10 cells in circuit this KCC becomes more energetic, and we get in addition a feeble ACC, and perhaps an equally feeble AOC. With 12 cells the KCC is very vigorous and may assume a tonic character (feeble KCT); ACC and AOC are stronger, especially the latter; KO is still without effect. Finally, with 14, 16, and 18 cells we get a powerful KCT, ACC, AOC, and last of all an evident but ill-developed KOC.

We may therefore conveniently distinguish three stages in the law of contractions. It is not, in my opinion, expedient to establish a larger number, although six and even more have been laid down. To extend the series would entail much confusion, and its members would not bear the constant relation in reference to different nerves which I can claim for the three stages which I have taken.

First Stage (weak current): KCC.

Second Stage (moderate current): KCC′ stronger. ACC and AOC also occur, of about equal strength, though sometimes one, sometimes the other appears a little earlier in different nerves. Thus ACC is usually first in the facial and ulnar, AOC in the musculo-spiral. These are small differences undoubtedly due to the anatomical position of the nerves and to the density of the derived currents instituting the virtual electrode (fig. 18), which is dependent thereon and causes the closure contraction.

Third Stage (strong current): KCC becomes tonic (KCT); ACC and especially AOC′ become more powerful, and at the same time weak KOC occurs (often hidden by the persistence of KCT till the current is broken).

Further stages do not occur in the living, healthy man; a further advance would be the occurrence of anodic opening tetanus, but this has, to my knowledge, not yet been observed in the healthy motor nerves of man. With very high strengths of current it is easier to produce a slight prolongation, with tonic character, of ACC.

For the notation of the law of contractions Brenner has introduced a very simple and practical formula, which contains the six possible exciting factors (KC, KD=kathodic duration, i.e. the period of closure of the circuit; what is termed closure tetanus is a KD reaction; KO, AC, AD=anodic duration and AO), by the side of which the strength and duration of the contractions may be appended in a manner readily understood. The following would be a formula for the three stages of the law of reaction of the motor nerve:

First Stage.	Second Stage.	Third Stage.
KCC	KCC′	KCC″
KD –	KD –	KDC >
KO –	KO –	KOC
AC –	ACC	ACC
AD –	AD –	AD –
AO –	AOC′	AOC′

It may serve to make the above-mentioned facts clearer if I add here a schematic representation of the different strengths of the contractions obtained by the several K and A, C and O excitations, having regard to their derivation according to the views just expounded concerning the polar actions and their underlying physical conditions. The strength of the individual contractions (C) in any nerve is, *cœteris paribus,* obviously the product of the amount of excitation of the active pole (P) and the density of the current at the point of excitation (D), i.e. $C = PD$. We will assume that the amount of excitation of the $K = 1$, of the $A = \frac{1}{2}$. We will represent these by simple numbers, and assume the density of the current at the active electrode (in the most shaded part of fig. 18) $= 1$, and that at the point of secondary polar action (shaded lightly in the figure) as $= \frac{1}{2}$. This is probably over-estimating it, just as the expression $\frac{1}{2}$ is excessive for the representation of the exciting effect of the anode

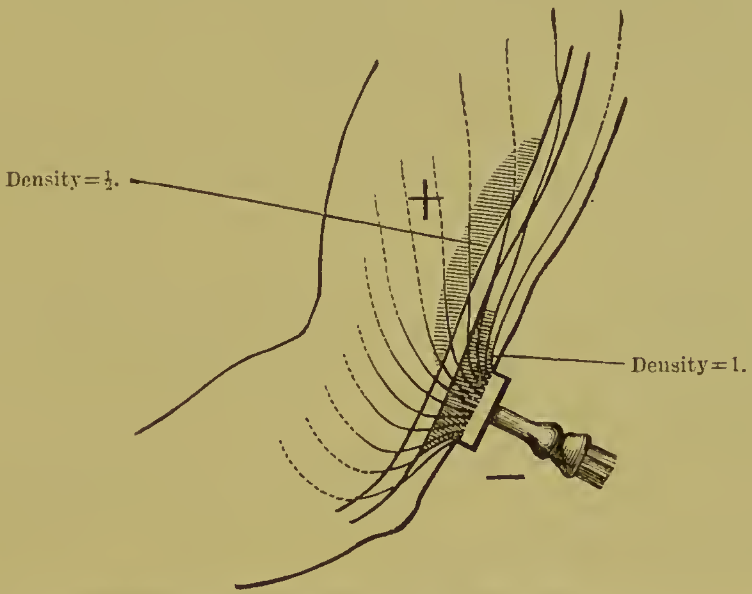

Fig. 18.—Diagrammatic representation of the varying density of the active (−) and the virtual (+) pole upon unipolar application of the kathode to the nerve.

with reference to the kathode taken as unity. But the two errors tend to rectify each other and the statement will serve well enough for the purposes of a schematic representation. It will entail no appreciable error to neglect the consideration of the threads of current which pass lower down, under the conditions of the method we have adopted.

Now let the exciting electrode be the K. When the current is closed it acts with an excitation force 1 and density 1. Therefore KCC $= 1 \times 1$. Consequently its strength $= 1$.

But on opening the current the excitation occurs not at the real K, but at the virtual A (lightly shaded in the diagram), with an excitation force $= \frac{1}{2}$ and density $\frac{1}{2}$. What we term the KOC therefore is of a strength $\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$.

Again, let the exciting electrode be the A. When the circuit is closed the excitation takes place not at the real A but at the virtual K (lightly shaded), with the kathodic excitation force $= 1$ and density $\frac{1}{2}$. The ACC has therefore a strength $1 \times \frac{1}{2} = \frac{1}{2}$.

But in this case on opening the circuit the excitation occurs at the A itself (darkly shaded in the diagram), with anodic excitation force $= \frac{1}{2}$ and density 1. AOC therefore $= \frac{1}{2} \times 1$ and its strength $= \frac{1}{2}$.

With a definite current strength, then, the contractions produced by the different stimuli arrange themselves in the following order and proportions:

KCC $= 1$ or 4
ACC $= \frac{1}{2}$ or 2
AOC $= \frac{1}{2}$ or 2
KOC $= \frac{1}{4}$ or 1

The attentive reader will readily understand that this series practically corresponds to observed facts, although the individual figures are inadequate to represent the actual strength of the individual contractions.[1]

The statements which I have made, gentlemen, hold equally for all the motor nerves in the human body, and you can demonstrate this truth in each so far as they come within your reach. You will find that they do not all behave precisely alike, but that, especially in reference to the part played by the ACC and the AOC and the comparative difficulty of inducing a KOC, they display considerable variation from one another. This arises, as we said before, from the anatomical peculiarities, and the diffusion of the current which depends upon them. You must therefore compare together only effects produced on the same portion of single nerves. It is not necessary to go fully here into the phenomena observed in all the nerves; you may find more on this subject in the works of Ziemssen and of Brenner, and you will derive still greater profit from a personal testing of these circumstances in all their details on appropriate individuals.

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[1] De Watteville has recently published (*Brain*, vol. iii. p. 23, 1880) a similar explanation of these phenomena. I would therefore remark that I have been for many years in the habit of introducing this scheme into my course of lectures on electrotherapeutics.

The former publications relate to experiments made without galvanometric record, so that no idea can be formed of the necessary current strengths. I therefore add here, as an example, some results of the galvanic investigation of several nerves in a healthy young man, from which one can readily gather the relative efficiency of the different stimuli in the several nerves. The method of investigation was the one usually adopted. I have indicated only the galvanometric readings and left out the number of elements, which are of no consequence.

The galvanometric readings given here are those at which the corresponding contractions first appeared. The 'standard' electrode was used. Resistance in galvanometer = 150.

KD means the appearance of tetanus (KT). The figures in brackets denote the current strength reckoned according to recent usage in milliampères.

Excitation	Accessory Nerve	Ulnar Nerve	Musculo-spiral Nerve	Peroneal Nerve
KC	10° (0·25)	8° (0·5)	10° (1·0)	20° (1·25)
KD	21° (6·0)	35° (4·0)	30° (8·0)	32° (6·0)
KO	28° (7·0)	35° (4·5)	35° (—)	39° (7·0)
AC	27° (1·0)	14° (1·75)	35° (4·5)	32° (4·0)
AO	15° (3·0)	28° (1·25)	25° (4·0)	27° (2·5)

From this you will appreciate the relative efficiency of the different stimuli in each nerve, as well as amongst themselves.

This table is instructive in reference to the order of appearance of AOC and ACC in the several nerves. You see that the accessory and the musculo-spiral react to AO much sooner than to AC. In the peroneal the AOC does not appear much before the ACC; in the ulnar much later. These relations are apparently the same in all healthy individuals, but even in the nerves where the ACC appears early the AOC speedily reaches the precedence with greater strength.

The electrical excitability of the voluntary muscles has been a subject of much contention and never-ending labour to the physiologist. The long-disputed question whether the muscles possess excitability of their own, independently of the motor nerves (or, more properly stated, whether the undoubted excitability of the muscles can be brought into effect by other means than through the motor nerves), appears now at last to be settled, and the existence of muscular excitability to be established beyond a doubt. This question, of purely theoretical interest to the physiologist, since the idio-muscular excitability is never taken into account in the normal organism, has nevertheless a considerable significance for us pathologists, inasmuch as, apart from morbid irritative processes in the muscular tissue itself, we often meet with morbid processes in which the idio-muscular excitability is demonstrable, independently of any action on the part of the motor nerves, and in which its determination subserves important diagnostic and prognostic purposes.

It has been found by physiologists that Dubois-Reymond's law of excitation also holds good for the muscles. It has been shown, however, that the muscular tissue has not the same property as nerves of reacting to currents of very short duration; hence its excitation by faradic currents is more difficult than by galvanic.

The muscles, however, respond to the faradic current like the nerves, with a contraction at each single induction shock of definite strength, and with a tetanic contraction to a number of such shocks rapidly succeeding one another.

The law of *galvanic* contraction for muscles has been variously given by successive observers. From the recent researches of Engelmann, Hering, and Biedermann it appears to be entirely analogous to that of the motor nerves, and to depend upon the fact that the closure excitation occurs only at the kathode, the opening excitation only at the anode. With moderate current strengths closure and opening contractions occur at both poles, but the latter are much weaker and often entirely absent. An opening contraction occurs regularly only with higher current strengths and very prolonged duration of closure; this is perhaps due to the fact that muscle reacts badly to short excitations, and that the break is such a short excitation. With strong currents a certain degree of shortening of the muscles persists after the closure as well as the opening contraction (closure and opening duration contraction; the latter is, however, difficult to obtain).

The direct muscular excitability is peculiarly difficult to test in the living man, where we are unable to excite the muscle itself independently of the nervous fibre distributed throughout its whole mass. We cannot draw conclusions from the instances where, owing to pathological conditions, the motor nerves are degenerated in their very terminations; for though the idio-muscular excitability is here present the fact that we have to do with pathological alterations of the muscular substance itself vitiates any conclusions we might draw. Still such facts prove the existence of an idio-muscular excitability, though we remain in uncertainty as to the exact physiological behaviour of the healthy muscular fibre in presence of electrical currents.

To the *faradic current*, when the automatic interrupter is used, living muscles react with more or less energetic tetanic contractions, according to its strength. To single induction shocks they respond with distinct contractions. These will be more marked according as the exciting electrode is applied more nearly to the place of entrance of the motor fibre—most evident, therefore, when this place (the 'motor point') is directly stimulated. Upon this fact depends the method of 'localised faradisation of muscles,' first employed by Duchenne, developed afterwards by Remak, and finally systematised in the hands of Von Ziemssen. By its means we are enabled to effect the faradic excitation of all the superficial muscles and of some that are more deeply situated.

The *galvanic reaction* of living muscle consists of a single closure contraction when both poles are applied to the muscle. An opening contraction occurs only exceptionally. This fact I have learnt as the result of numerous experiments; and in those I found it necessary to avoid the motor points as far as possible, a precaution which can be observed only in the case of the long and powerful muscles, such as the biceps brachialis, the extensors in the thigh, the deltoid, and vastus internus, the pectoralis major, and the like. This absence of an opening contraction may perhaps be accounted for, as I have already said, by the relatively slight excitability of muscle to an opening stimulus of short duration. The closure contractions are rapid and vigorous. Still it has often seemed to me that they were less prompt and lightning-like than those produced through the nerve. They occasionally too displayed a tendency to tonic spasm. But they are in no case precisely sluggish.

Another thing to be observed is that the KCC is at times but little better marked than the ACC, and this affords a striking contrast to the normal reaction in the nerve. Jolly has noticed the same thing, and he has even found ACC > KCC. In explanation of the phenomenon much light is to be derived from the noteworthy statements of Hering, who points out that, with the usual disposition of the electrodes, the several parts of the muscle that are respectively anodic and kathodic must have very complicated relations under different conditions of shape, size, situation, and anatomical structure. If you reflect further that the substance of the muscle under examination is, relatively to the neighbouring soft parts, of far greater extent than the nerve similarly investigated, and that in consequence the former receives a much greater quantity of the current, and that so the 'virtual' electrode is rendered more efficient, and also that the afferent motor nerve must occasionally fall under the influence of the virtual electrode, while the muscle thus becomes comparatively more excitable to KC than to AO, you will not, perhaps, arrive at any sufficient explanation of the phenomenon, but you will find it equally a matter of astonishment that its reaction should differ only so slightly from that of the nerve.

It is obvious that a *localised galvanisation* of the different muscles is also possible, and its methods and principles are the same as those upon which the faradic current is similarly employed.

There is another and a very important class of effects produced by the action of the electric current upon motor nerves. These are its *modifying* or *electrotonic* effects. They are those which are expressed by a change—increase or diminution—in the condition of excitability—chemical, physical, or mechanical —of motor nerves and muscles, which is effected by the passage of the current through these structures and lasts for a variable time afterwards. These effects have been made the subject of the closest physiological research, and they have been combined under the name of 'electrotonic phenomena.' To Pflüger belongs the credit of having investigated them exhaustively in all their bearings, but a few words will suffice to lay before you as much of the matter as is essential or instructive to us.

A galvanic 'polarising' current, passed along the course of a motor nerve, modifies its excitability throughout, but with greatest intensity in the vicinity of the two poles. Under the kathode and around it there is a more or less considerable increase of excitability to the various orders of stimuli; and this is called *katelectrotonus.* At the anode, on the other hand, and in its neighbourhood there takes place a diminution of excitability, and this is known as *anelectrotonus.* Both are in proportion to the duration and intensity of the polarising current, and the two conditions approach each other at a central spot in the intrapolar space. The modification of excitability is greatest at the electrodes and falls off in a curve on either side.

When the polarising current is opened the negative modification of excitability at the anode (anelectrotonus) gives way to a very remarkable positive modification or increase of excitability, which lasts for some time. At the kathode, on the other hand, there is first a negative modification of short duration, giving place quickly to a positive modification of a high degree—a considerably increased excitability. This disappears as slowly as the other, and the normal condition is restored. On opening the current, therefore, there remains at either pole a state of increased excitability of variable continuance.

Inasmuch as in pathological conditions we have reason to believe that we have commonly to do with states of increased or diminished excitability of the nervous structures, and since moreover it has always been a great temptation to electrical therapeutists to reduce the results they have obtained to the exact and obvious phenomena of electrotonus, it has followed that numerous efforts have been made to define and establish these phenomena as displayed in the living man. Notwithstanding the great difficulties with which they have been surrounded, these efforts have met with a considerable measure of success in all essential particulars. The demonstration of a law of motor contractions in the live subject may itself be regarded as a proof of the existence of electrotonic modifications.

The first attempts in this direction, which were published almost simultaneously by Eulenburg and myself, yielded diametrically opposite results. Eulenburg's conclusions were in harmony with the doctrines of physiology; whereas mine—derived, it is true, from different nerves, but by a similar method—were at variance altogether with these. Thus I found the excitability increased in the neighbourhood of the A and diminished towards the K. I afterwards tested the accuracy of this view on many occasions and in various ways, and it seemed to me to be beyond question. Its explanation, as Helmholtz pointed out directly when my observations came under his notice, was to be found in the rapid diffusion of the current in proximity to the polarising electrodes; so that the virtual poles were formed in the neighbourhood of each, thus constituting an opposed influence, as may be seen in the diagram (p. 77), which I have already explained to you. When, by the light of this interpretation, I applied the exciting electrode close to or upon the polarising electrode, I obtained the ordinary effects precisely as in physiological experiments.

It may be well, in illustration, to place before you the results of some of my experiments. They were mostly made in my own person, on the ulnar nerve. The two polarising electrodes were placed above the nerve in the upper arm, 10 to 12 centimetres apart. For the purpose of excitation I employed secondary faradic currents, conveyed to the nerve by means of a fine electrode, taking care in various ways to modify the circumstances of the experiment. The distance of coils at which minimum contractions occurred were noted alternately during the passage of the current and on opening the circuit. In the first group of experiments which I shall relate to you the excitation took place a little below the situation of the polarising electrodes; in the second it was effected at the place of application of the polarising electrode, which was perforated for the purpose. You will readily perceive that in the first instance there was always a diminution of excitability in the katelectrotonic and an increase in the anelectrotonic zone, while in the second the usual results—increase in the katelectrotonic and diminution in the anelectrotonic—were uniformly obtained.

1st Series of Experiments—Exciting Electrode below the Polarising Electrode.

A. *Descending Katelectrotonus.*

Polarising Current	Distance of Coils in Mm. for Minimal Contraction				Diminution of Excitability in Mm.
	Exp. 1	Exp. 2	Exp. 3	Exp. 4	
12 cells, opening	54	54	50	55	5–15
closure	49	42	38	40	
14 cells, opening	55	48	48	—	9–12
closure	46	36	36	—	
16 cells, opening	45	44	55	55	8–14
closure	37	32	42	41	

B. *Descending Anelectrotonus.*

Polarising Current	Distance of Coils in Mm. for Minimal Contraction				Increase of Excitability in Mm.
	Exp. 1	Exp. 2	Exp. 3	Exp. 4	
10 cells, opening	48	45	46	42	6–10
closure	54	52	54	52	
12 cells, opening	44	45	41	43	6–11
closure	51	51	49	54	
14–16 cells, opening . . .	36	41	40	54	9–11
closure . . .	46	50	50	65	

2nd Series—Exciting within Polarising Electrode.

A. *Descending Katelectrotonus.*

Polarising Current	Distance of Coils in Mm. for Minimal Contraction				Increase of Excitability in Mm.
	Exp. 1	Exp. 2	Exp. 3	Exp. 4	
10 cells, opening	50	52	58	—	12–14
closure	63	66	70	—	
12 cells, opening	55	62	61	57	10–18
closure	65	72	75	75	
14 cells, opening	58	—	56	—	27–30
closure	85	—	86	—	

B. *Descending Anelectrotonus.*

Polarising Current	Distance of Coils in Mm. for Minimal Contraction				Decrease of Excitability in Mm.
	Exp. 1	Exp. 2	Exp. 3	Exp. 4	
8 cells, opening	52	54	—	—	20–21
closure	32	33	—	—	
10 cells, opening	58	58	65	—	21–30
closure	37	32	35	—	
12 cells, opening	53	51	54	—	34–36
closure	19	17	18	—	

The evidence of these figures is incontestable. They prove beyond doubt the possibility of effecting electrotonic modifications of excitability in the living subject.

These phenomena have already been studied by other observers (Samt, Brückner, Runge, von Ziemssen), but the results of their investigations are very different and often contradictory. For the most part their methods have been faulty. Nothing positive has been published by them, and the exactitude to which Samt lays claim, somewhat pretentiously, has not been vindicated by the nature of his conclusions. The experimental methods of Brückner and Runge are so complicated and involve so many indeterminate factors that it is useless to try and build anything substantial upon them. It is therefore still to be desired that the subject should be investigated in a closer and more scientific manner.

Since the above was written careful researches by means of improved methods have been undertaken by Waller and de Watteville, with the result that they have established beyond all doubt the existence of electrotonic phenomena in the living man, and they confirm the conclusions which I originally drew with the aid of very primitive resources. These writers have adopted the unipolar method of excitation exclusively, and they have so far approved of the coincident localisation of the polarising and exciting current that they transmit them both through the same electrode. They have shown that during the passage of the polarising current two zones are formed in the nerve—a 'polar' zone immediately under the polarising electrode and of the same electrical character as the latter, and a 'peripolar' zone (our virtual electrode) beyond this and of the opposite character—further, that the exciting electrode similarly determines the formation of two opposite polarisation zones in the nerve, so that KC excitation takes place in the polar, KO in the peripolar zone, and this is reversed for the A. They have proved these facts by excitation with the induced current, with the galvánic current (K and A, C and O), and finally with mechanical stimuli applied during the period of polarisation. The results of their numerous experiments are altogether in harmony with the doctrines of physiology. They make it evident that, during the passage of a galvanic current, excitability is increased at the kathodic, and diminished at the anodic zones, both polar and peripolar. When the polarising current is opened the excitability at the kathode is at first momentarily diminished and then exhibits an increase of long continuance; at the anode it undergoes a notable diminution from the outset, and this persists for a long time afterwards.

Thus it has ceased to be a matter of speculation whether the electrotonic effects can be produced with any certainty in the motor nerves of the living subject. But my researches, not less than those of Waller and de Watteville, serve to emphasise a fact which was already sufficiently evident from *à priori* considerations—namely, that the conditions of the observations in this case are far more complicated than in that in which we have to do with an excised nerve-muscle preparation; for we cannot here submit considerable stretches of nerve fibres to a polarising influence of a similar and accurately determinate character throughout, but we have to reckon commonly with six, or, when the unipolar method is used, at least three, distinct parts of the nerve, displaying various conditions of anelectrotonus and katelectrotonus. This will be seen more readily in the accompanying diagram (fig. 19). The recognition of this fact

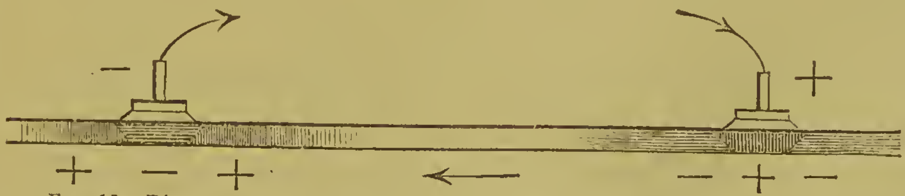

FIG. 19.—Diagram showing the effects of a bipolar excitation of a nerve, when the electrodes are applied to the skin. The area of anelectrotonus is shaded vertically, that of katelectrotonus longitudinally.

alone did much to render the investigation fruitful in tracing the therapeutical results of electricity to its electrotonic effects.

But the question of the condition of excitability during the passage of the polarising current possesses for us only a secondary interest; of far more importance in therapeutics are the subsequent and more persistent changes of this kind, the (possibly lasting) modifications which remain when the circuit is opened. We learn from physiology that under these circumstances there persists at either pole and almost throughout the entire length of the polarised nerve a more or less exalted condition of excitability; but the analogy from its speedy decline and the subsequent restoration of the normal state of things would encourage but little hope of securing for these changes the desired permanence in circumstances of disease.

Efforts have been made to demonstrate these 'after effects' in the uninjured nerve of the living subject, but they have been attended with as great difficulties as those for the solution of the previous problems. The earlier experiments are entirely without significance. The methods upon which they were conducted were faulty, and their conclusions ill-founded and unreliable. The same may be said of the otherwise admirable researches of Brenner on the subject of the *secondary* and *tertiary* excitability of motor nerves, by which is meant the changes induced in this condition by alternate reversals of the current. The increase of excitability effected in this way seems often to have been considerable; but, inasmuch as the current strength at each excitation was not determined by the galvanometer, it is questionable whether that apparent increase was real and not rather due to a diminution of tissue resistance, brought about by the action of the current. This latter was at all events an efficient factor in the phenomenon, and further and more accurate experiments can alone determine the measure of its influence. Hitherto this has been attempted only by E. Remak; but he has added to the already very great difficulties of the undertaking by confining himself to the study of the *strictly polar* modifications of excitability, and by the somewhat capricious exclusion of the faradic current as an exciting agent. He has arrived at the following conclusions: Kathodic duration produces a positive modification of the KCC, whereas this is but little marked with anodic duration and requires for its display a special disposition of the circumstances of the experiment. Having regard, however, to the inconsiderable deviations of the galvanometer, by which these differences are effected, and to the many sources of error to which such conclusions are exposed, I am not inclined to look upon them as finally established. The labours of Waller and de Watteville, on the other hand, have yielded conspicuous results in this direction too. They found that the facts here, as in other respects and as I had already anticipated, were in complete agreement with the teachings of physiology; and they would seem to have proved that the cessation of the polarising current was followed by a long-persistent (as much as 1½ hour), positive modification of excitability.

Under the name of the *refreshing action* of the current Heidenhain has described the modifying action of the galvanic current upon muscles that have become fatigued and exhausted by protracted electrical excitation. He found that when these muscles had ceased to be excitable they could be rendered so again by the persistent action especially of an ascending galvanic current. But, inasmuch as this restoration of excitability depends upon the opening excitations of a current similarly directed and the closure excitations of one in an opposite direction, it has come to be regarded as merely the manifestation of an electrotonic phenomenon of the same nature as that witnessed with voltaic alternatives. In connection with the living subject there is nothing known about it.

LECTURE VI.

Electrophysiology of the Sensory Nerves and Nerves of Special Sense—Sensory Nerves of the Skin and their Law of Reaction—Sensory Nerves of the Muscles—Optic Nerve and Retina—Acoustic Nerve and the Nervous Auditory Apparatus—Nerves of Taste—Nerves of Smell.

After what we have said of the effects of electricity on the motor nerves, and especially in presence of the imperfection of our knowledge concerning the reactions of the nerves of general and special sensation, the electrophysiology of the latter will not delay us long.

With regard to the sensory nerves of the skin, the question arises much more forcibly whether the galvanic current excites them by its continuous flow, or only by variations of density. At all events the application of a pole, with a current of sufficient strength, to the skin causes a continuous sensation, a peculiar itching and pricking, which soon passes into a uniform burning: the latter may increase to a very severe pain. This sensation, especially the uniform burning, may be largely due to the irritating effect of the chemical substances which are set free at the surface of the body by electrolysis and act like a mustard poultice or other rubefacients; to some extent, however, it is probably caused by the direct action of the current upon the sensory apparatus of the skin. Physiologists are not yet agreed as to the explanation of the latter phenomenon. Many lean towards the view that the sensory terminal organs react to the current differently from the conducting paths—that they are not excited by variations of density only, but also by the constant passage of the current. This is, to a certain extent, opposed to the fact that continuous excitation of a nerve trunk—that is, of conducting fibres—is accompanied with a continuous eccentric sensation in the region of its distribution. On making the experiment on the ulnar at the elbow or the median at the wrist, a lively eccentric sensation of formication is experienced in the fingers at KC and during KD, gradually diminishing; at AC and during AD the sensation is the same, but weaker. Grützner has lately made fresh researches concerning the continuous excitation of sensory nerves by the galvanic current.

It is well known that experiments on animals throw but a very imperfect light upon the phenomena presented by the sensory nerves. A so-called law 'of contraction,' or rather 'of reaction,' of these nerves has been obtained in an indirect manner only, inasmuch as the reflexes occurring upon excitation of them (in slightly strychninised animals) were taken as indications of the sensory excitation. By means of this method Pflüger found the law of reaction of sensory nerves to be in complete harmony with that of the motor nerves, *mutatis mutandis*, i.e. with the differences necessarily produced by the altered course of transmission in sensory nerves (for the third stage).

I am not aware that physiologists have lately made any attempts to establish a law of reaction for the sensory nerves in man. It is true that any efforts to do so on the principle of a directional influence of the current would lead to hopelessly confused results, and the investigations of the laboratory are too apt to be biassed by mistaken views on this point. The principles established in the foregoing pages show that for the sensory nerves of the human subject the polar method of investigation is the only one which can be employed, and that our task consists in determining the reaction of these nerves at both poles on making and breaking the current and with different strengths of current. Researches lately made by myself have shown me that this is perfectly practicable and that there is a striking similarity in these respects between the polar law of motor contraction and that of sensory reaction.

The sensory excitations produced by the galvanic current appear not only in the part of the skin covered by the exciting electrode, but also in the region of distribution of those sensory nerves of the skin whose trunk lies within the area of influence of this electrode. With arrangements indentical with those applicable to motor nerves, and gradually increasing current strengths, a brief KC sensation appears first, which with a stronger current passes into a persistent pricking, eccentric, and local sensation, the intensity of which gradually diminishes during KD; then follows a similar, feebler, short AO sensation; somewhat later a weak AC sensation, which only passes into an AD sensation with still stronger currents. Finally, with a relatively great current strength, if the KD sensation has been allowed gradually to subside, a weak but distinct KO sensation makes its appearance. During the entire experiment a lively burning skin-sensation is felt in addition to the feeling of pricking, confined exactly to the surface of contact of the electrode. Here it is evident that in sensory nerves also the kathode produces chiefly a closure reaction, the anode chiefly an opening reaction, and that the exciting effect of the kathode predominates greatly over the other.

As an example I give the results of two experiments on the median nerve and on the cutaneous branch of the radial at the outer side of the forearm. The investigation was conducted in the usual manner, the indifferent electrode being at the sternum or behind the neck. The current strengths at which the several reactions occurred are given in terms of the deflections of the galvanometric needle, and these reactions are ranged in the order of their appearance.[1]

Excitation	Median			Radial		
	Old Galvanometer	Absolute Current Strength, Stand. Electr.	Absolute Density	Old Galvanometer	Absolute Current Strength, Stand. Electr.	Absolute Density
KC	20°	0·75 ma.	0·075	20°	0·75 ma.	0·075
AO	26°	1·75 ,,	0·175	26°	1·75 ,,	0·175
KD	34°	3·0 ,,	0·30	34°	3·0 ,,	0·30
AO	34°	2·5 ,,	0·25	35°	3·0 ,,	0·30
KO	40°	6·0 ,,	0·60	39°	6·0 ,,	0·60
AD	45°	8·5 ,,	0·85	45°	8·0 ,,	0·80

The general coincidence is apparent, and will likewise be appreciated when we compare the results obtained on a sensory and on a motor nerve; for this purpose I take the results obtained on the peroneal and exhibited above (p. 83).

Reactions of Sensory Branch of Radial.		Reactions of Motor Nerve—Peroneal.	
KC	20°	KC	20°
KD	34°	KD	32°
KO	39°	KO	39°
AC	35°	AC	32°
AO	26°	AO	27°

A more striking analogy could hardly be desired.

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[1] The second and third columns respectively show the absolute current strength in milliampères—standard electrode (see Lecture VIII.)—and the absolute density of the current as determined by the new method.

The sensation produced by the action of the *faradic current* upon the cutaneous nerves is a peculiar one; every induction shock causes a short, stabbing sensation, which increases, if the interruptions are rapid, to a continuous pricking, and (especially under the use of dry metal electrodes or the metallic brush) to a burning and most painful sensation. If a sensory nerve trunk is excited, a peculiar eccentric pricking sensation and a feeling of tightness is experienced in the entire region of distribution; this effect is much stronger on excitation with the K of the break induction current than with the A. Individual shocks are not so painful as rapidly repeated ones, and the intensity of the faradic sensation, or the pain, increases with the rapidity of the interruptions.

Waller and de Watteville have recently investigated the *electrotonic effects* of the galvanic current upon the sensory nerves of the skin (with faradic, galvanic, and mechanical stimuli), and they have established a complete accordance with the phenomena observed in the motor nerves. Spanke (under the direction of Rumpf) has arrived at similar conclusions. By his researches in connection with the galvanic water bath he has shown that there is an increase of the sense of space under the K and a diminution under the A, and that these changes are perceptible in the vicinity of either electrode.

Similar results have been derived for the sense of *touch* by R. Graeber, who made use of the Hering-Knoll æsthesiometer for the purpose.

The *sensory nerves of the muscles* cannot be readily examined when isolated, except in muscles which have been laid bare by wounds, disease, or operation, and in complete anæsthesia of the skin; under these circumstances, however, a sensory impression has never been observed in the muscles without a simultaneous contraction. The only conditions in which this factor could be eliminated would be found in a case where the reaction of degeneration and anæsthesia of the skin, only, co-existed. Every vivid muscular contraction is accompanied by a distinct sensation, which has nothing in common with cutaneous sensations and may increase to actual pain during tetanic contraction: this constitutes the so called 'electro-muscular' sensibility, which has been demonstrated by Duchenne with induction currents only. It is a peculiarly dull, tensile sensation, which is directly proportionate to the amount of muscular shortening. This sensation becomes distinct with strong galvanic currents also, as soon as they produce a tetanic contraction of the muscles. Its test may be of interest in certain pathological states, but does not possess the importance attached to it by Duchenne. Moreover it is often rendered impossible by the admixture of sensations arising from the simultaneous excitation of the sensory nerves, the skin, periosteum, &c.

Much more interesting results have been furnished by the electrical investigation of the nerves of special sense, or rather of the organs of special sense, for we have here to deal chiefly with the excitation of terminal or end organs, retina, cochlea, semicircular canals, &c. As a matter of course such results can be tested upon the human subject only, and, accordingly, they have given rise to much less experimentation upon the part of physiologists.

With regard to the electrical excitation of the organs of special sense, it may be premised that on the whole they react very slightly or next to not at all to the *faradic* current, and the powerful excitations required to obtain a result exert a disturbing influence upon the observation by producing considerable effects on the cutaneous nerves.

On the other hand, these organs react to the *galvanic* current with comparative, or even with extreme, readiness, and they do this each with its specific sensation—the eye with light, the ear with sound, the tongue with taste, the nose with smell. It can be easily shown that these sensations depend on the action of the two poles and obey strictly the law of polar influence. It is clear that we always have to do here with a direct galvanic irritation of the nervous apparatus of the special senses in question, a fact which has been over and over again demonstrated by every kind of experiment. The opposite view, formerly defended with obstinacy, but now upheld but by a few partisans, and that somewhat diffidently, was that the sensory impressions were reflex and due to excitation of the trigemini. It has been so completely refuted as to scarcely deserve a mention here.

The *eye*, i.e. the optic nerve or retina, reacts by far the most readily to the galvanic current. You need only to pass a very weak current through the temples or cheeks, to see flashes of light appear on making or breaking the current, their intensity growing with every increase of the current strength. You may make the same observation if somewhat stronger currents are applied at some distance from the eye—to the neck, for instance, or even to the chest and back—a sign of the great sensibility of the retina to galvanism, since such weak derived currents as reach it under these circumstances still suffice to excite it.

The optic reactions have been the subject of many electro-physiological experiments, some very insufficient, others most thorough and scientifically conducted, and various explanations have been given of them. Volta, Ritter, Grapengiesser, Reinhold were succeeded by Purkinje, whose observations were numerous and important; more lately Brunner, Funke, and chiefly Helmholtz have investigated this subject. Helmholtz describes very accurately the sensations of light and colour in his variously modified experiments, and seeks to explain them on the basis of the laws of electrotonus with reference to the direction of the current in the retina and the fibres of the optic nerve situated therein. Most physiologists, however, have not been able to liberate themselves from the tendency to ascribe importance to the direction of the current, and speak of the effects of an ascending and descending current in the optic nerve. Some have indeed spoken of polar action, but have not distinguished between closure and opening effects. In truth, there never was a more unprofitable undertaking than the endeavour to explain those luminous sensations by differences in the direction of the current. The expansion of the optic fibres in the retina, and perhaps we may add the fact pointed out by Pflüger, that the minute terminal branches of this nerve turn upon themselves as they leave the layer of nerve fibres to enter that of the rods and cones, and so assume a direction altogether opposed to that of the fibres in the optic nerve itself—these are anatomical considerations which suffice to show the futility of the attempt, even though it should be conceded that the luminous phenomena are, in fact, derived from the excitation of the optic nerve and not of the retina.

Brenner has suggested, and proved by careful experiments, that the galvanic excitation of the optic apparatus is a polar effect, and that the effects differ with the pole which stands in proximity to the eye. We are thus in a position to establish a simple law of reactions for the nervous organs of sight.

On the application of either pole to the eye, a lightning-like sensation of light is felt upon making and breaking the current, but which differs qualitatively (different colours) with opening and closure. The sensations of light and colour at KC are qualitatively like those at AO, and those at AC like those at KO, so that each pole shows the opposite colours at make and at break. For example :—

	Experiment A.	Experiment B.
KC	reddish light	whitish yellow
KO	bluish ,,	blue
AC	bluish ,,	blue
AO	reddish ,,	whitish yellow

With a current of moderate strength the sensation is that of a sudden flash of light, like that of diffused lightning, illuminating the dark field of vision and permitting sometimes, only with much difficulty, the recognition of a more or less distinct colour ; this latter may be so decided that both poles may thereby be clearly distinguished from one another after a little practice.

In many individuals capable of accurate observation a still more precise differentiation occurs, chiefly when the current is somewhat strengthened, inasmuch as a peculiarly light-coloured, shining patch, usually circular, more rarely rectangular (Purkinje) or rhombic, appears in the centre of the field of vision ; this is surrounded by a paler glimmer of light as a sort of halo. The colours appearing on kathodic and anodic closures and openings show here also an inverse disposition. When the current is strong they persist for a time during closure and disappear gradually. The opening reaction is temporary only and seldom attended with any after sensation. The brilliant central disk has an apparent diameter of 4 to 6 millimetres, and lies to one side of the visual axis, viz. to the right of the fixed object when the right eye, to the left when the left eye is excited, and at such a distance from it that the point of entrance of the optic nerve must be the point of origin of these spectra. An example will make this subject clearer:—

KC	blue centre, yellowish green halo
KO	yellowish green centre, bright blue halo
AC	yellowish green centre, bright blue halo
AO	blue centre, yellowish green halo

The colours and the order in which they appear vary greatly in different persons, but they are always alike in the same individual. In my own case KC gives me a brilliant yellowish central disk surrounded with a dark aureola. The field of vision becomes generally darker. AO produces a similar sensation. AC calls forth a pale bluish red centre, with a pale red aureola, and the field of vision is generally lighter. The same sensations follow KO, but I never could distinguish between the sensation of light and that of colour.

Neftel, on the other hand, has been led by the results of his experiments, which otherwise agree with those of Brenner, to conclude that the optic reaction consists of two effects, one of light, the other of colour, the one preponderating over the other or being present alone in certain individuals. He also mentions a sensation of increased intra-ocular tension under the kathode, of diminished tension under the anode.

The chief phenomena of the galvano-optic reaction in most individuals who possess a certain gift of observation can be obtained with readiness with very low current strengths (4–6–8 elements), the indifferent electrode being placed upon the neck or sternum, the exciting one upon the closed lids or the temples, in a moderately darkened room.

It is noteworthy from a theoretical point of view that KC and AO, and also KO and AC, produce sensations qualitatively identical. One might feel inclined to draw the conclusion that K at opening and A at closure have a specific exciting effect, different from that of the closure excitation of K and of the opening excitation of A; but it is more correct to assume, in consonance with the general physiological data, that the difference is due to a change in the locality of excitation by

KO and AC, where these must be regarded, according to the views expounded previously, as secondary polar effects of the virtual A and K.

It would obviously be most interesting and important to know whether the galvano-optic sensations occur from excitation of the retina, or of the optic nerve, or of the layer of nerve fibres in the retina. Without entering upon a discussion of this point I may say that I am not aware that any proof exists that the one or the other of these views is correct. Experiments in appropriate pathological cases would doubtless lead to something more definite.

Let me take this opportunity to make brief mention of the reactions of the iris to electrical currents. Its muscular tissue reacts readily to the faradic current, as shown by numerous experiments, and by a suitable arrangement and localisation of the electrodes the sphincter pupillæ and dilator pupillæ can even be made to contract separately; the same effect is obtained by exciting their nerve trunks (oculo-motor and cervical sympathetic).

The latter result has not been obtained with certainty on the human subject, as we shall see when we speak of galvanisation of the sympathetic. The direct excitation too has been tried by but few observers (Duchenne), and is possible, indeed, only in chloroform narcosis or anæsthesia of the cornea. Two fine wire electrodes (best connected to the same pole, the other pole being fixed anywhere on the trunk) are applied opposite one another 2 to 3 mm. from the edge of the cornea: with a sufficient strength of the faradic current marked contraction of the pupil occurs. But this point is of no practical import.

The *galvanic reactions of the acoustic nerve*—or rather of the auditory nervous apparatus—are important both from a theoretical and a practical point of view. From the earliest times of electrophysiological enquiry the question whether the acoustic nerve reacted with a specific sensation (of sound) has been warmly debated. Brenner in his great work gives a historical sketch of the antecedent experimental researches, and sums them up by saying that 'it is uncertain whether the acoustic nerve reacts to galvanism; and if so, how it reacts.' The labours of Brenner mark the commencement of a new era. It fell to his lot to establish the galvanic reactions of the auditory nerve in a manner that admits of no further question, and he has shown that its laws are closely analogous to those of the motor nerves. It is a truly classical instance of experimentation, which yielded an ample harvest of physiological and pathological data and settled this point, so that his successors have had only to confirm his results and uphold them against unfounded and superficial objections. The exhaustive enquiry of Hagen and myself, as well as those of Hedinger, Hitzig, Erdmann, Eulenburg, and others, are sufficient to disprove the assertions of Hensen (Hermann's 'Handbuch der Physiologie,' vol. iii. 2, p. 126), which betray a complete ignorance of the subject and establish the fact of the acoustic reactions to galvanism obeying a strict law.

Excitation of the acoustic nerve in healthy persons is by no means an easy task, and many failures in experiments made to confirm the law of its reactions doubtless arise from that fact. The nerve is situated so deeply that strong currents are necessary to excite it; and these give rise to such disagreeable concomitant phenomena (from excitations of the eye, sensory nerves, nerves of taste and salivation, facial nerve, and especially the brain) that many healthy individuals can only accustom themselves gradually to perceive and observe correctly the auditory sensations. It is, indeed, impossible for some people to obtain this result at all; and were it not for the fact that there are so many patients suffering from ear diseases in whom the nerve manifests a considerable increase in its galvanic excitability, whereby the existence and regularity of appearance of the acoustic reaction can easily be demonstrated, we would, perhaps, still be hopelessly searching for the law of excitation of the normal and healthy auditory apparatus. Still with perseverance, patience, and self-sacrifice on the part of the subject, and practice and dexterity in the experimenter, it is usually possible to determine the law in the majority of healthy individuals.

Formerly the meatus was filled with water, and a fine wire or sponge electrode introduced, whilst the indifferent electrode was held in the hand or on the sternum. This so called 'internal method of investigation' is painful and faulty, as the presence of the water gives rise to disturbing extraneous sounds. I have, therefore, used an external method, already known to Brenner, which is less unpleasant to the subject of the experiment and yields satisfactory results.

A moist sponge electrode, larger and best of the 'medium size,' is placed and firmly held immediately in front of the auditory canal, pressing slightly upon the tragus, but without occluding the canal or filling it with water. The indifferent electrode is most advantageously placed on the nape of the neck. The strength of the current is to be gradually increased, and repeated kathodic closures, and now and then AC, are made; or, if the excitability is very low, repeated current-reversals; the person experimented upon is directed to pay as close attention to his auditory sensations as possible, disregarding the concomitant phenomena.

You will thus arrive at an extremely simple formula which results from the fact that the normal acoustic apparatus reacts on kathodic excitation only by a closure sensation or sound, on anodic only by an opening sensation or sound, the former being much more lively and appearing earlier than the latter. The normal formula, therefore, of the acoustic nerve with moderate current strengths is merely KS (sensation of sound). With stronger currents, on the other hand, it is as follows:—

KCS	loud sound
KO	no effect
AC	no sound
AOs	weak sound

The quality of the sounds elicited varies in different individuals, but less so among those with healthy than those with morbid acoustic nerves. Normal individuals usually describe the sound as more or less loud whistling or hissing, but also as a ringing, humming, or buzzing, like the noise of boiling water, of wind blowing, of bees flying, &c. The AO reaction is usually very weak and short. With increasing strength of current the sensations rise in intensity, distinctness, and duration, and assume a rather musical, and whistling, or singing character: they pass from the original buzzing, &c., into more or less pure tones, which, however, are not unfrequently accompanied with noises.

By means of experiments performed upon himself while the organ of hearing exhibited the condition of galvanic hyperæsthesia, Kiesselbach maintains that with galvanic excitation the quality and pitch of the note obtained was under all circumstances the same without reference to the mode of investigation or the strength of the current, and this note he believes is determined only by the resonance of the conducting structures. The fact is significant but requires further demonstration.

The KC excitations with higher current-strengths are distinguished by their more intense and persistent effects: the acoustic sensation is not momentary, but disappears only gradually, during the period of closure of the circuit. This fact made Brenner assume a kathodic duration reaction (KDS), comparing the sensation which persists during the period of flow to its analogue, the KCT of the motor nerves. Hence the complete normal formula of the acoustic nerve is as follows:—

KCS′	loud sound
KDS >	sound diminishes and disappears
KO	no sound
AC	”
AD	”
AOs	short, weak sound

The strength of current required to demonstrate this formula differs with different individuals, but is always about the same for the same person. The KC reaction is far more easily obtained than the AO reaction, which is more readily produced after the current has been allowed to flow for a certain time. Thus we find that in one of the nerves of special sense the law laid down for the polar actions in physiology—viz. that the K excites only on closure, the A only on opening—is exemplified with remarkable precision and completeness; and it is highly interesting to read in Brenner and others how perfectly the acoustic reactions conform to the phenomena observed in the motor nerves with reference to every other particular, such as their behaviour to duration, commutation, repeated closures, simple changes of density, &c.

We ask ourselves, naturally, why it is that only pure polar effects are obtained in this nerve. According to our previous statements an anode is inevitably present in a nerve on which rests a kathode, and here, as in the motor nerves, we should expect to find, upon excitation with the kathode, the simultaneous action of the secondary or virtual anode. Why does this not happen in the case of the acoustic nerve? Hitzig has endeavoured to explain this phenomenon by reference to the anatomical relations of the nerve—its position in a bony canal, its direct transition into the brain mass, the divergence of the acoustic fibres on reaching the central organs—these peculiarities rendering the density of the threads of current, which should produce the secondary polar action, so slight that they will usually remain ineffective. We shall see that in certain pathological conditions, however, these effects (KO and AC reactions) may also be developed, whether owing to changes in the conductivity or in the excitability of the nerve. It is also possible that only the peripheral end organs of the nerve can be excited by the galvanic current, and that these always react exclusively under the influence of the nearest pole, while the effect of the other (virtual) pole only occurs at the central end of the nerve, which is perhaps not at all excitable, or at least not with such weak currents.

We are also ignorant of the precise nature of the so called excitation of the auditory. Is it an excitation of the nerve trunk itself or of its terminal branches and end organs? With our present knowledge, I think, we are not in a position to answer this question. Our uncertainty on this point, however, in no way invalidates the certainty and uniformity of the galvanic auditory reaction, or detracts from its practical value in diagnosis and therapeutics.

Attempts have been made to excite the auditory by means of an electrode passed into the Eustachian tube, and even introduced within the cavity of the tympanum. This was done at the suggestion of Brenner. In these experiments the galvanic sensations of sound were not wanting; but they have been conducted by a very limited number of observers, and inasmuch as the question possesses a very secondary interest in connection with therapeutics we need not stay to discuss it.

The same remark applies to the subject of the direct excitation of the internal muscles of the ear by way of the tympanic cavity, which has been for many years under discussion and still remains unsettled. It should be the concern of aural specialists to push to some useful conclusions an enquiry which certainly is not devoid of interest. Cl. J. Blake maintains that he has observed the effects of electrotonus in the auditory, as exhibited by an exalted perceptive sensibility of the organ of hearing for high musical notes of from 3,000 to 8,000 vibrations per second when under the influence of the kathode.

Of all the nerves of special sense the effects of galvanism upon the *nerves of taste* are those which have been longest known, as they were also those which were most studied by the older galvanists.

With the simplest galvanic elements, e.g. a piece of zinc and copper, placed on the tongue we can produce a peculiar acid, salty, metallic gustatory sensation, which with stronger currents readily appears upon the application of the electrodes to the cheeks, throat, temples, mastoid processes, and the neck. This is the so called galvanic taste, which is extraordinarily prone to occur even on galvanisation of distant parts and proves the great galvano-excitability of the organs of taste.

A more careful examination—as when, for example, a medium electrode is placed upon each cheek—teaches that distinct gustatory sensations occur on each side (i.e. at both poles), but that they are very different on the two sides. On the anodic side the sensation is decidedly more marked and metallic, alkaline, or perhaps very acid; on the kathodic it is feebler, sharper, saltish, constricting, and never, according to Vintschgau, alkaline. The difference is so striking that most people can readily distinguish the A from the K by this means, if not on the first trial at least with some practice.

Here, then, we also find that the continuous passage of the current is accompanied by a continuous sensation, as the taste is not present upon making and breaking the current only, but also during the period of its passage, although indeed it rapidly diminishes and disappears with weak currents; when the current is strong, however, the sensation persists for a long time.

The question has often been raised whether one has not to do here with an action upon the gustatory nerves of actual sapid matters, such as acids and alkalies set free by electrolysis, instead of a simple electrical excitation with specific effects. Physiologists are still discussing this question, which moreover does not interest us much. I imagine that its solution will not be reached easily, any more than that of the problem whether the excitation affects the terminal organs of the nerves themselves.

We know little concerning the *olfactory nerves*, the electric excitation of which is a difficult undertaking. The older observations, including those of Althaus, are not free from objections. E. Aronsohn, however, has quite recently published the result of some very instructive observations which he has effected on his own person. He introduced a glandiform nasal electrode within the nose, previously filled with a 0·73 per cent. saline solution at 38° C., placing the indifferent electrode upon the sternum. In this way he established a law of olfactory reaction quite analogous to that of the auditory. With KC and AO only there was a peculiar and characteristic sensation of smell, this being less pronounced with AO than with KC. The sensation was produced with current strengths of 0·1 to 0·2 ma. The faradic current had no effect.

LECTURE VII.

Electrophysiology of the Secretory and Vasomotor Nerves—The Cervical Sympathetic—The Action of Electric Currents upon the Skin—Electrophysiology of the Brain and Cord—The Effects of Galvanisation upon the Brain and Cord in the Living Subject—Electrophysiology of the Thoracic and Abdominal Viscera—Electrolytic and Cataphoric Effects—The Galvanic Introduction of Remedies within the Body—Catalytic Effects derived by Remak—Indirect Catalysis.

We come now to consider the electrophysiology of certain other parts of the nervous system. They are those of which little is known as yet that can be applied to the object which we have immediately in view, but for the most part their study involves considerations that possess the utmost interest for us.

With reference to the *secretory nerves*, which ever since the valuable discovery of C. Ludwig have attracted much of the attention of physiologists, we have as yet acquired but little useful information. Experiments upon animals, it is true, have thrown much light upon many points, to which you will find reference made in the text-books of physiology. In the living subject such researches have not yielded any very instructive result. It is known that when a galvanic current is passed transversely through the cheeks or in the neighbourhood of the ear, and when the auditory nerve is excited, a copious secretion of saliva takes place; but it is still an open question whether this effect is due to direct excitation of the chorda tympani or to reflex stimulation of the nerves of taste and sensation in the mouth and pharynx.

When a galvanic current is applied to the region of the cervical sympathetic in a particular manner (which, however, does not necessarily exclude the extension of its influence to the brachial plexus), the secretion of the sweat glands is locally stimulated in the face and hand of the corresponding side (Mor. Meyer). With energetic faradisation of the tibial nerve Adamkiewicz asserts that he brought about a copious secretion of sweat in the foot. According to him, too, the same effect is produced in the palm when the radial is excited, and in the face when the trunk of the facial is stimulated. He regards the act of secretion as an associated effect (centrifugal excitation) of stimulation, whether voluntary or electrical, of the motor nerves. Subsequently he obtained the secretion in the course of faradisation with the brush; only here it was more abundant and poured out in the parts directly excited as well as others more remote. He looks upon this as partly a reflex phenomenon.

This is all that is positively known of the action of the secretory nerves in the living subject.

Nor is our knowledge more extensive in connection with the vasomotor nerves. I am not aware that physiologists have as yet investigated the condition of electrical excitability in these nerves. There is no such thing as a 'law of contractions' of vasomotor nerves. All our information upon the subject is comprised in a mass of unintelligible facts. Thus we know that when these nerves are faradised the vessels contract and afterwards dilate; that when they have been regularly submitted to the action of the current for some days previously dilatation is the immediate and primary effect of excitation; when they are galvanised and both poles used there is at first contraction and then dilatation of the vessels; the current strength being increased, dilatation occurs earlier, but not in a regular manner; and more hopeful is the discovery of Przewoski, that KC is followed by a lowering and AD by an increase in the temperature of the parts supplied by the excited nerves.

For another fact of the utmost consequence in electrotherapeutics we are indebted to the researches of Grützner. He found that for one class of vasomotor nerves—the dilator fibres of the cutaneous vessels—the galvanic current is a direct excitant. When a current is allowed to pass continuously for several minutes in either direction along the sciatic nerve of the dog, a primary dilatation of the vessels takes place without previous contraction and independently of opening and closure excitations.

If you have followed the course of modern physiological research in this domain it will cease to be a matter of surprise to you that everything is still enveloped in doubt and uncertainty. True the question that has of late engrossed so much of the attention of physiologists as to whether these nerves contain vasodilator as well as vasoconstrictor fibres may be thought to have reached its final solution; but until we are in a position to distinguish one class of fibres from the other, and to separate their respective functions with some approach to precision, we cannot expect to learn much of their nature.

The difficulty of the situation is necessarily enhanced in dealing with the human subject. I shall point out to you presently, when speaking of the electrophysiology of the sympathetic, and again in connection with the cutaneous effects of the current, whatever information we possess in the matter.

I ought to mention here an observation, comparable to those of Grützner, which I made on my own person a long time ago. In the course of some experiments which I had undertaken for another purpose I applied a stabile current to the inner surface of the forearm by means of a pair of medium-sized electrodes. The application lasted for about 20 minutes. I had 6 to 12 cells in circuit and occasionally reversed the direction of the current. In the situation of the lower electrode a circumscribed reddish halo was all that was noticeable; at the upper one, however, the redness spread all over the radial border of the forearm, and extended beyond it for a considerable distance over the posterior surface. I next applied a faradic current, and I found by the sensations produced that the area of redness corresponded to the distribution of some small cutaneous filaments which happened to come within the influence of the superior electrode. This area had not been submitted to the direct action of the current.

The electrophysiology of the *sympathetic* next engages our attention, and it is a subject of much importance as bearing upon certain questions of a clinical nature, and because its proper understanding will involve the solution of many complicated problems. Here we are concerned especially with the sympathetic in the neck, since in the present condition of science it is that part alone that possesses any practical interest.

The cervical sympathetic, as you are aware, is a nervous structure of which comparatively little is known as to its functions. It supplies, to begin with, the vasomotor fibres to the vessels of the face and skull, in part also those of the brain and orbit, and perhaps of the upper extremity as well. It includes in its substance the fibres that preside over the secretion of sweat, and those that determine dilatation of the pupil, and others that govern the condition of the eyeball (muscle of Müller). Finally, it sends its branches to the heart, and we know not where else besides. Thus we see that its relations are sufficiently complicated, and it presents peculiar difficulties in investigation! Even in the lower animals this has been attended with very partial success. The teaching of physiology is briefly as follows:—

In *faradisation* of the cervical sympathetic there is first contraction and then dilatation of the vessels of the corresponding side of the head and face. At the same time there is an increase of the mean pressure in the brain—referred by G. Fischer to stimulation of the vagus and sensory nerves—dilatation of the corresponding pupil, widening of the palpebral aperture, slight exophthalmus, and acceleration of the heart's action.

The effects of *galvanisation* are less marked. Many physiologists have failed to find any in the pupil and the blood vessels of the head. Landois and Mosler, however, assert that they have seen dilatation movements of the pupil follow the galvanic excitation of the exposed nerve. G. Fischer has endeavoured unsuccessfully to obtain this result in the head of a decapitated criminal. In this instance rapid reversals of the current caused only a permanent dilatation, and the appearances attributable to the vasomotor nerves were equally equivocal. In these, again, it is impossible to establish any law of response, notwithstanding that the duration of the current appears to have some influence.

Since the time when R. Remak invested the process of galvanising the cervical sympathetic with a great clinical significance the question, in its application to the living human subject, has repeatedly been opened, but as yet we have not made any progress to its definitive solution. There are many circumstances that tend to increase the difficulty of acquiring information upon men as compared with animals. In the first place the sympathetic is more deeply situated in the neck ; it is thus less easily accessible, and the proximity of so many vital structures —as the vagus and carotid plexus, the base of the brain and medulla oblongata, and the cervical and brachial plexuses— which it is impossible to avoid with the only means of excitation at our disposal, while their effects are equally impossible to eliminate—all this places anything more than a probable interpretation of phenomena entirely beyond our reach. Experiments have resulted for the most part in confusion. Each new observer contradicts the last. The most opposite conclusions have been drawn, and it behoves us to employ the utmost discretion in adopting any of them. This, in a few words, is what is supposed to have been established.

Faradisation of the cervical sympathetic is followed by dilatation of the pupil of the corresponding eye, contraction of the vessels, characterised by pallor and coldness of the same side (temperature lowered in cheek 0·5° to 1·75° C.) succeeded by a sensation of warmth (temperature increased 0·5° C.—Przewoski). With reference to dilatation of the pupil this point is doubtful. The effect may be due to a skin reflex (Erb, 'spinal myosis and reflex rigidity of the pupil').

The *galvanisation of the sympathetic* in the neck is effected either by applying (1) one electrode in the mouth, the other outside at the angle of the jaw; or (2) one at the manubrium sterni, the other at the angle of the jaw; or (3) one at the angle, the other on the lower cervical vertebræ. It has been reported that several symptoms are thus produced. Thus *changes in the circulation*, as seen in the retina, or on the face (sometimes anæmia, sometimes hyperæmia), are said to occur. Przewoski states that he has noticed, when the kathode was on the ganglion, a lowering of the temperature in the hand and cheek on the same side; when the anode, a slight augmentation in the same parts.

Modifications of the pupil: dilatation, according to Gerhardt, Mor. Meyer, Eulenburg and Schmidt ('often very slight'), sometimes also an ulterior contraction; but this is very uncertain, and most likely in a great measure due to a skin reflex. *Influence on the heart*: diminution of the blood pressure and frequency of pulse, changes in the sphygmographic tracings (Eulenburg and Schmidt, Beard), equally doubtful. *Elevation of the temperature and perspiration in the hand* (Meyer), *feeling of somnolence and vertigo* (Beard and Rockwell), also very uncertain.

G. Fischer reached this main conclusion: that the effects of the galvanisation of the sympathetic ('subaural galvanisation,' de Watteville) are to be ascribed chiefly to the excitation of the pneumogastric and of the cutaneous nerves.

Though the physiological results are thus unsatisfactory it nevertheless appears certain that the cervical sympathetic can be influenced by the current. Pathological observations support this view: thus Otto, in a woman suffering from an affection of this nerve and presenting cerebral symptoms with intense erythema and perspiration on the same side of the face, saw the redness diminish and disappear for a long time under the influence of the kathode. In a case of atrophy of the sternomastoid, and in which therefore the sympathetic could be reached more easily, I saw the labile application of the kathode produce a dilatation of the pupil and increased redness of the cheek. M. Meyer, in a case of apoplexy, found the hyperæmia and heat of the ear subdued by galvanisation of the sympathetic on the same side. Seeligmüller found, in a case of injury of the sympathetic, that the pupil reacted with great energy to electrisation of the nerve; and probably there exist more observations of the same kind. But, even after adducing all we know on the subject, we must confess that the galvanisation of the sympathetic in the living man offers but a very unsatisfactory basis for the bold generalisations as to its therapeutical importance. I shall return to this subject.

We now come to the effects of the current upon the *skin*, which to a great extent rest upon vasomotor effects. Here also the conditions are as complex as that structure itself, which comprises the chorion, the blood and lymph vessels, the cutaneous muscles, the sweat glands, and their nervous supply. It is not easy to determine the action of electricity on each of these various elements.

You all know the *redness* observed at the points of application of the electrodes, and which no doubt is due to the vascular dilatation and afflux of blood. But a more careful observation teaches us that other phenomena occur according to the mode, intensity, and duration of the electrical action. The following are the most important:—

When the skin is faradised with wet electrodes and moderate current-strength, the effect is not marked; but with stronger currents a momentary pallor may be noticed, with *cutis anserina*, to which a more durable redness succeeds. When the brush is used these phenomena are much more marked; the stage of pallor passes quickly, giving place to an intense hyperæmia of longer duration, but which disappears without leaving any trace. The intensity and duration of these phenomena vary greatly with the portion of the skin excited and in different individuals.

When the skin is galvanised with moderate currents, if it is sensitive, there occurs, besides the pricking and burning sensation previously mentioned, an intense redness at the two poles, of variable persistence. Papules or even blisters of some size may be formed. The hyperæmia may remain for hours; repeated application leads to desquamation of the epidermis. With strong currents of longer duration these effects are more readily obtained, and the action of the poles is found to differ. At the kathode you often see at first a pallor, then a rosy tint, of the skin; the latter becomes infiltrated and whitish phlyctenæ appear. Around this region a halo of dark red is noticed; when the electrode is removed the skin underneath remains very red for a long time. At the anode an intense scarlet redness appears at once or after a period of pallor; there is no infiltration, but granular rugosities are seen. This redness persists for a long time, and desquamation is abundant.

When the current is very intense the discoloration may persist for a remarkable time; I have seen the spots of application redden again from six to ten days after, under the influence of certain excitations applied to the skin, such as a vapour bath.

It is difficult to determine the respective share taken in the production of these phenomena by the vasomotor nerves, the peripheral centres lately described, the cutaneous muscles, the circulation of the lymph, the mechanical conveyance of liquids from anode to kathode. It is not even easy to say whether the difference observed at the two poles is one of quality, and not quantitative only, as Ziemssen maintains. I should incline to the latter opinion were it not for the undoubted agency of the electrolytic effects of the current.

The latter are certainly the cause of the well-known *caustic action* of the kathode. When a small metallic kathode is placed on the skin, and the other pole in the shape of a large moistened sponge or plate is applied at some other spot, a strong current rapidly produces, amidst much burning, a vesicle filled with an opaque, strongly alkaline liquid. After removal of the electrode this vesicle turns into a small brown eschar, which falls after a long time, leaving a loss of substance, with permanent cicatrix. When the anode is used in the same way the results are not so marked; the brightness of the electrode is tarnished by oxidation, and the vesicle contains an acid liquid.

When the electrodes are moist and well padded, you do not observe these effects, but if there be any defect or irregularity in the padding vesicles are produced. Many patients carry scars produced by negligence of this simple precaution, a fact which is not to the credit of those who are responsible for giving them unnecessary pain.

It is clear, then, that we can produce marked changes in the circulation and nutrition of the skin by means of galvanic currents—a fact which clearly proves the possibility of producing similar effects in other tissues, and thus influencing pathological conditions of these functions. It is true that we cannot act with the same energy upon deeply placed organs and with currents of the same density as on the skin; but, after all, it may not be always necessary to do so to obtain therapeutic effects.

The physiological effects of the current on the *brain* have been much investigated; but it is only during the last ten years that satisfactory results have been obtained and the exposed brain shown to be excitable. Hitzig and Fritsch's researches have opened a new era and dissipated as if by magic the darkness which surrounded the question. They succeeded in showing that certain cortical areas, carefully submitted to a galvanic or faradic excitation, reacted by setting up muscular movements in the opposite side of the body. I need scarcely insist upon this point; you all know the consequences of these experiments, the questions they have raised, and the discussions on the importance of these 'motor zones' or 'centres,' as they are generally called. I need only mention the fact that anodic closure (AC) excites more powerfully than kathodic closure (KC), the latter being more active on peripheral nerves. This remarkable difference may be due to the difference in the chemical reactions of grey and white nervous matter: peripheral living nerve fibres have an alkaline reaction (Funke); cortical grey matter is always acid. The white cerebral matter is neutral or feebly alkaline (Gscheidlen). Closure of a weak or moderate current diminishes excitability to the same pole, increases it to the other: voltaic alternatives or current reversals are thus the most powerful excitants. The induced current has been used almost exclusively by Ferrier in his researches.

It has been long known that the corpora striata and a part of the corona radiata respond to electric excitation by movements; the other effects produced—sensory, psychical, vertiginous—cannot obviously be ascertained on an animal. Hitzig in his researches started from experiments on rabbits, in which he found that strong currents through the head produced curious movements of the eyes, observable in man also.

With reference to the living man it had long been stated that the brain, in its osseous case, was not to be reached by the current. My experiments, now universally accepted, have refuted this doctrine, which Remak and Benedikt had already attacked on clinical grounds. Several interesting symptoms occur on passing a galvanic current through the head. But it must be here remembered that faradisation from without has as little effect on the brain as it has on the nerves of special sense.

The best way to secure the passage of the current through the brain is to direct it transversely through the temples or mastoid processes, or longtitudinally from the forehead to the occiput. The first phenomenon generally observed is giddiness, which has been studied by Brenner in connection with his experiments on the acoustic nerve, and by Hitzig. It consists in a disturbance of equilibrium, at first subjective only, but which may become objective and take the form of an oscillation of the head and of the upper part of the body, and may even cause the patient to fall. There may also be a sense of rotation of surrounding objects, or the body itself may appear to turn round.

On the strength of numerous experiments it may be said that the giddiness is the greater the more nearly the direction of the current is at right angles with the longitudinal axis of the skull. Thus the effect when the electrodes are applied to the temples or mastoid processes is marked, whereas when they rest on the forehead and occiput it is very slight.

Currents with a transverse direction were shown by Brenner to produce on closure a notable swaying towards the anode, on opening a less marked effect towards the kathode. The same results are observed when one electrode only is applied to one side of the head and the other is held in the opposite hand. AC and KO produce a swaying towards the electrode, AO and KC away from it. During the experiment the feeling of swaying is much more vivid than the actual movement; with closed eyes the swaying seems more violent than is really the case. The sensation is as if the weight of one half of the body was removed, and thus a fall on the opposite side ensued. When the current is strictly longitudinal these sensations are absent; neither do they occur when a divided anode or kathode is applied to either side of the head and the other electrode rests on the neck or trunk.

A vertiginous feeling persists during the whole time of application of a transverse current, if at all strong. There is apparent rotation of surrounding objects, and the patient has the feeling of a loss of equilibrium. The rotation may seem to follow an ascending course from the anode, descending to the kathode, or it may take a horizontal direction from anode to kathode. When the current is broken the apparent movements occur in the opposite direction. They are quite independent of the objective lateral swaying of the body, and are considered by Hitzig as being rather due to certain ocular movements determined by the electrical excitation.

These *ocular movements* themselves appear to be produced by the vertiginous feeling and disturbance of the muscular sense, which occur when the current is of a certain strength. Hitzig was the first to observe them and described them accurately. When a strong current is sent through the mastoid processes, associated nystagmus-like movements of the eyes occur in a definite direction ; thus if the anode be on the right side the two eyes are driven to the left, and are maintained there with an oscillatory movement. This phenomenon is not due to the direct excitation of any motor centre or fibres, and does not possess any practical importance.

Many people experience also, on galvanising the head, a certain peculiar *cerebral symptom*, as of stunning and the like, and even of *syncope*, which may become real in individuals of great sensitiveness, in whom the psychical impressions may perhaps play a part. A sensation of *nausea*, and even vomiting, has been observed.

All these symptoms are certainly due to the penetration of the current and its effect upon the encephalon. The theory that they are due to the excitation of the sensory organs is untenable, because, on the one hand, they occur without any such excitation, and on the other hand this excitation may be strong without having any such effect. We are ignorant, however, of the portions of the brain which give rise to the phenomena under consideration and of their physiological explanation. The most interesting point is the mode of production of galvanic vertigo, and several hypotheses have been propounded. I take the following to be the most plausible: It is certain that the brain contains bilateral organs for the reception of afferent impulses necessary to the maintenance of equilibrium; and, *cæteris paribus*, our sensation of stability in space depends upon their equable and symmetrical excitation. When the galvanic current is sent across the brain one half is influenced by the anode, the other by the kathode, and thus under opposite electrotonic conditions. In other words, the excitability of the former is diminished, that of the latter increased. Hence similar excitations on the two sides will produce different effects, and a loss of equilibrium ensues. The sensation of giddiness is produced, and the oscillations of the body which occur are efforts to overcome the subjective loss of balance. We need not discuss here the question whether the organs implicated are the semicircular canals (Hinze) or the cerebellum (Hitzig); we need only allude to the opinion of Löwenfeld to dissent from it, viz. that these phenomena depend upon changes in the circulation.

The experiments of Hitzig and Ferrier on the excitability of the motor centres led to the endeavour to obtain the same results on the living man, in whom pathology demonstrates the existence of such regions. My experiments on the intact skull have hitherto failed, perhaps owing to the insufficient current strength used. An American observer (R. Bartholow) took the opportunity afforded to him by a case of cancer of the skull to introduce fine needles through the dura mater into the ascending parietal convolution, and he successfully excited the brain with faradic currents.

In a case of injury with hernia cerebri in the surgical wards at Heidelberg (Prof. Czerny) I was unable to obtain any result from electrisation of the brain carried out with much care and in various ways. It could scarcely be otherwise, indeed, considering that the opposite side of the body was paralysed.

Charcot, however, has lately succeeded in several cases of hysterical somnolence (with nerve and muscular hyperexcitability) in producing contractions in the opposite side of the body by excitation of the skull in the neighbourhood of the motor centres. The contractions could not be obtained in the waking state. He was not invariably successful with these lethargic patients. In some the contractions were best marked on the same side as the excitation, and in others they were altogether absent. It is needless to add that such manifestations in hysterical somnolence must be accepted with the utmost caution.

With reference to the *spinal cord* physiological experiments have yielded even fewer results than in the case of the brain. There is divergence of opinion as to the electrically excitable portions of the exposed cord. No experiments have been made on the cord intact and within the body ; the result of introducing needles into the vertebral canal, and exciting its contents by means of very powerful faradic currents, has been to produce generalised tetanic convulsions.

Researches have been made on the modifying action of galvanic currents upon the spinal cord. J. Ranke, who pursued the line of investigation of Nobili and Matteucci, found that in the frog reflexes are diminished or abolished by currents of a certain strength flowing in a longitudinal direction. Legros and Onimus state that this is the case with descending currents only, and that ascending currents often increase reflex action. Uspensky regards the cord as a peripheral nerve which is thrown into anelectrotonus or katelectrotonus and presents corresponding modifications with reference to the reflex and respiratory functions. All these contradictory inferences have been arrived at by methods which do not eliminate the influence of sensory excitation and carry but little scientific weight, whilst clinical observations intended to prove the sedative or antispasmodic value of the galvanisation of the back furnish data from which no certain conclusion can be drawn as to the physiological action of the current on the spinal cord.

With reference to the *living man*, erroneous physical views had likewise led to the belief that the cord could not be reached by the current, owing to its bony protection. My experiments on the dead body, confirmed by Ziemssen and Burkhardt, showed the cord to be accessible to currents applied properly just as much as other equally deep-seated structures. On the living subject two large plate electrodes are placed over the spine, and strong currents with voltaic alternatives are sent through. When kathodic shocks are made on the lumbar region contractions of the leg muscles occur, showing that the current has excited the nerve roots within the bony canal. Brenner says that sensations in the legs are also produced by this method. The results of numerous therapeutical experiments also leave no doubt as to the reality of the permeation of the cord by currents applied from the outside, though from a physiological point of view we can say nothing as to the action of electricity on this organ.

The remaining organs of the body need but a brief mention.

With reference to the thoracic viscera—*the lungs and heart*—they have as yet hardly been submitted to the investigations of electrophysiologists. Consequently we know little or nothing about them. I will merely mention here that it is possible to bring about the movements of coughing by means of a particular application of the current (Brenner). This may best be done by placing the kathode at the nape of the neck, with the anode upon the spinal column, and closing or reversing the current. The cough produced is accompanied by a sensation of tickling in the throat. It may be caused in many persons when the higher electrode is over the dorsal region, in the neighbourhood of the thoracic cavity.

I have already alluded to the questionable influence of galvanisation of the sympathetic upon the heart's action.

Von Ziemssen has recently published some interesting observations upon electrical excitation of this organ. They were derived from a man in whom the heart was rendered accessible (being covered only by the skin) in consequence of an operation upon the thoracic walls. Here he was able, by means of strong galvanic currents, to produce an immediate effect upon the form and energy of the contractions, as well as upon the rhythm and frequency of the beat, and to stimulate the heart directly through its motor ganglionic apparatus. He found that when strong currents were used and reversed regularly with a frequency greater than that of the heart's beat, the latter was increased to the rapidity of these reversals. Similarly it could be accelerated by passing a strong unbroken current through certain points in the ventricular walls. On the other hand it was not possible to retard the heart's action with anything like the same certainty. We would expect similar results to obtain with the thoracic parieties intact. The researches of E. Herbst in this direction have been fruitless. Perhaps they were conducted differently from those of von Ziemssen, or the currents used may have been too weak. At all events he failed to elicit the effects which physiological considerations would induce us to look for. Dixon Mann has arrived at conclusions of a like negative character, and further investigations are desirable.

The *abdominal organs* are mostly endowed with unstriated muscular fibres, which may be shown to react to electrical stimuli; the liver is the least so, and does not appear in man to be affected by electrical currents. The gall bladder is said to have been made to contract, especially when distended, as in catarrhal jaundice (Gerhardt), by means of external faradisation; but it is difficult to accept this assertion.

Enlargements of the spleen have often been treated electrically, but without any definite results, though experiments on animals allowed of some hopes in that direction. The faradic current has generally been preferred to the galvanic. Some observers (Chvostek, Berger, Botkin, Skorczewsky, Popow, &c.) state that chronic swellings of that organ have been reduced either by the direct or the reflex action of the current; others (Mosler) have not been so fortunate. Either wet electrodes or faradic brushes have been used to the skin over the organ. I do not feel justified in forming a definite judgment on this question.

The electrophysiology of the digestive tract gives us a firmer ground to tread upon, since its muscular constituents obey, generally speaking, the laws of motor excitation.

The muscular fibres of the *pharynx and soft palate* are easily excited by galvanism and faradism. Moderate currents applied with appropriate electrodes produce local contractions; stronger currents cause movements of deglutition and a sense of choking.

A more important fact is the ready production of movements of *deglutition* in healthy people by galvanisation. When the anode is placed behind the neck and the kathode, with a current of from 6 to 10 cells, is rapidly passed along one of the sides of the larynx, swallowing is visibly and audibly produced at each excitation. The subject of the experimentation feels as if a mouthful of food or drink compelled him to swallow. Brenner showed that, on placing the electrodes so as to obtain unipolar excitations, the movements of deglutition occurred chiefly at KC and AO, according to the law of nerve reaction.

The effect here is evidently a reflex phenomenon, starting from the sensory nerves of the pharynx and larynx—that is, the vagus and especially its superior laryngeal branch. This view is supported by recent physiological experiments upon the mechanism of deglutition. The theory which was formerly held, and which would ascribe the movements in these experiments to excitation of the hypoglossals, may be shown to be incorrect by varying the mode in which they are performed.

The *œsophageal muscles* may be readily excited with suitable electrodes. Great caution, however, is necessary, on account of the proximity of the vagi, and the use of too strong currents may be attended with ill consequences.

The *unstriated muscles of the stomach and intestines* are known to react to electricity in an evident manner. The resulting contractions are of a peristaltic character, and they continue after the withdrawal of the stimulus. In this respect the faradic current is the more effective of the two.

Energetic faradisation of the abdomen has been seen in cases of large inguinal hernia, or where the integument was tense and thin, to be followed by perceptible and visible movements of the bowel and stomach, which were further evinced by a gurgling sound. Using the manometer to determine the mechanical effect of these movements, Bäumler has arrived at negative, and von Ziemssen at positive, conclusions. Moreover the latter has found in experiments on animals that, not the entire stomach, but only the part excited contracts, and that the pyloric responds more actively than the cardiac end, to either current. As a further effect of faradisation Schliep observed that a quantity of fluid which had been introduced into the stomach was quickly removed, and he asserts that excitation of the intestine was frequently followed by defœcation. The chief evidence of the influence of electricity upon the coats of the stomach, however, is of a clinical kind, and is drawn from cases of dilatation, dyspepsia, and chronic obstruction. But as yet we know little of its *modus operandi.*

The alimentary canal can be reached in various ways—percutaneously, with one electrode on the back while the other is applied, stabile or labile, to the abdomen, strong currents being used, so as to produce energetic contraction in the abdominal muscles; or one electrode (either specially made or an œsophageal sound) may be introduced within the stomach, or a rectal electrode may be passed into the rectum and the other applied as before to the abdominal walls. This proceeding is absolutely painless.

The *rectum* may be excited in the same way as the rest of the intestines. The sphincter ani is governed by the laws of contraction and it may be reached by an appropriate electrode.

The electrical excitation of the *bladder* is a point of great clinical importance. It is easily effected; but the subject has not yet been sufficiently studied from a physiological point of view. Here again Bäumler failed to find any manometrical indication, and we are forced to content ourselves with the evidence to be derived from diseased conditions. If an electrode is passed along the urethra as far as the neck of the bladder and a current transmitted, there are perceptible contractions of the sphincter vesicæ and the urethral muscles, which are frequently sufficient to expel the electrode with considerable force. The bladder may be excited by either current, and percutaneously or by introducing one electrode in the bladder and the other in the rectum.

Nothing is known as to the physiological action of electricity upon the *kidneys* and *ureters*, or upon the *testicles* and vasa deferentia of the living subject.

We are equally ignorant of its effects upon the non-gravid *uterus*. To act upon this structure either current may be used, and the electrodes may be introduced within the vagina or within the cavity of the uterus itself. Here again there is abundance of clinical evidence, of which you shall hear more by-and-by. Bayer makes certain somewhat unsatisfactory statements with reference to the production of uterine contractions by means of galvanism. He placed one electrode, shaped like a sound, within the cervix, the other upon the symphysis or on the lumbar spine. It was only in some cases that any effect was to be seen, but in these the sound was moved backwards and forwards and sometimes expelled bodily from the uterus. With KC the movements of the sound indicated a prolonged contraction, which was equally marked with AC.

We are indebted to the same author for some remarks upon the excitation of the uterus in pregnancy and labour. He found the galvanic current the more effective in inducing labour. He placed the K in the cervix and the A on the fundus, and with a current of 12 to 16 cells passed continuously (for 10 to 15 minutes) he was able to bring about regular normal pains, and that whether labour had already begun or not. The excitation was more effective in the first than in the second stage of parturition. Unfortunately in these experiments the galvanometer was not used to determine the activity of the current.

E. Bumm, on the other hand, has found that the effect of electrical excitation upon the uterus of the rabbit is to produce a slow tonic contraction, and that the effect of the A in this respect is greater than that of the K. In investigating the subject further upon the gravid uterus he obtained no result with the faradic current, and with the galvanic could only produce slight and irregular contractions. He did not venture to reverse the galvanic current *per vaginam*, through misconceived apprehensions of its caustic effects. It was only by introducing the electrodes within the uterus that the faradic current could be made to cause contractions. Excitation of the uterine nerves and plexus by way of the rectum or vagina was altogether inoperative.

I come now to speak of the *electrolytic* and *cataphoric* effects of electricity. Of these but little is definitely known, and yet there is an overweening tendency to ascribe to the action of the currents in this direction many of their most important therapeutical results. It follows from what has been already said that we are concerned here almost exclusively with galvanism; not that the faradic current is entirely without an action of this kind, but we can afford to neglect its consideration, inasmuch as it is in its degree greatly inferior to the other.

From the nature of things, unfortunately, but little information can be derived from experiments upon the living animal.

Electrolytic phenomena can be clearly seen only at the surface of the body, where the metallic conductors of the current may be brought in contact with the tissues. Thus, as has been pointed out above (p. 115), it is possible by proceeding in a particular way to demonstrate in man the formation of acid vesicles at the positive, and alkaline at the negative, pole. If the process is pushed further evident cauterisation is produced.

But it is difficult even to speculate upon the processes that are set up within a conductor of so complex a character as the animal organism during the passage of a current—the possible electrolytic and molecular effects produced in the various tissues, and the extent to which the vital interchange is promoted or impeded. Physiologists have determined that there is a sort of internal polarisation, which is displayed under given conditions; and they have made use of this discovery to explain many of the physiological phenomena of nerves and muscles. But as to what is the nature of these processes, what are the molecular changes effected, and what the resulting chemical substances—of these things we know nothing.

Drechsel, however, has made a remarkable discovery bearing upon this matter. He succeeded in forming urea by electrolysis of carbonate of ammonia by means of voltaic alternatives. It is at least probable that a similar process takes place within the system during life.

So far as the living human body is concerned the entire subject is involved in obscurity, and we can only fall back upon conjecture. In this there has been no lack of enterprise and ingenuity; and in truth there is a great temptation to indulge in hypotheses concerning the action of electricity in this respect, for there are few fields in the domain of science that offer so wide a scope and so attractive a prospect to a bold imagination. But the misfortune is that men are content to cherish illusions in the face of opposing facts. For this reason we are obliged to dismiss such preconceived ideas concerning the possible electrolytic phenomena of the human body. I shall have occasion, however, again to revert to this subject in connection with the therapeutical effects of the current.

We stand upon somewhat firmer ground when we come to speak of the so called *cataphoric* actions. In one direction at all events they have been made the subject of experimental research, which has placed them upon a definite and tangible basis. As yet this is not satisfactory in regard to the percutaneous application of the current, which is almost alone resorted to in medicine. It has been the fashion to ascribe to the causes which are classed under this heading certain appearances, such as the depression and anæmia, and the roughness and dryness of the skin in the situation of the A, the formation of blisters at the K, and the absorption of excessive exudations under the influence of the current. Remak led the way in this, but we are still free to raise the question whether these appearances may not be due to other causes. Still it is highly probable that these cataphoric actions do obtain in the human system, as in the bodies of the lower animals, notwithstanding Bernhardt's conclusions to the contrary.[1]

A remarkable application has lately been made of the cataphoric action of the current. Von Bruns had already proved that iodide of potassium could be made to pass through the human body, whether alive or dead, by means of a galvanic current. To Munk, who conducted many experiments for the purpose, is to be attributed the best method of utilising this property, a method by which he succeeded in introducing medicinal substances with the utmost certainty through the uninjured cuticle in such a way that they were eliminated by the urine and saliva, or might be recognised by their toxic effects. This he did as follows: He took two of Dubois's conducting tubes, closed with plugs of clay. Both the tubes were filled with a saturated solution of the substance to be introduced, and the plugs were also moistened with it. These were then applied to the body, and currents of moderate strength passed through the parts in the same situation. Their direction was reversed every 5 or 6 minutes, because it was found that the activity of the process diminishes with the continuance of any one current. For the same reason it is necessary to charge both electrodes with the substance used. In this manner it is possible to introduce a considerable quantity within the system in a period varying from 15 to 45 minutes. Strychnine cramps have been produced in the rabbit, and in man traces of iodide of potassium and of quinine administered thus have been found in the urine for hours afterwards. The effect is proportional to the surface area of the electrodes and the current strength, and it is increased by removing the epidermis from the part where the former are applied. When this method is adopted in practice certain limitations should be recognised. The substance to be introduced should be taken in small quantity, for these experiments have been successful only with medicinal agents of great energy and in diminutive doses. Moreover it cannot be made to penetrate deeply within the body or to traverse considerable structures. This is an effect of the rapid diminution of the current density. It follows that we can only procure the immediate absorption of these substances and their conduction through the system by means of the blood. A local action of any kind is possible only in the case of the skin or the smaller joints, or upon tumours situated immediately below the skin and in such a position that they can be included between the two electrodes.

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[1] Bernhardt's experiments do not seem to me to warrant the conclusions which he has drawn from them. It is not merely the water, but all the fluid constituents of the tissues with the substances held in solution that we must assume to be put in motion under the cataphoric influence of the current. The estimation of the percentage of contained water cannot therefore yield any useful inference as to the propulsion of the organic liquids, since there is not sufficient difference between the water element and the other fluid constituents of the remaining tissues (we are here concerned with the brain) to present notable differences under the conditions of the method adopted.

The elder Remak has judiciously observed that the principal actions of the galvanic current in diseased conditions must necessarily be of a complex nature. The knowledge of its exciting and modifying effects upon nerves and muscles is not adequate to explain the cures which it has been made to work. These for the most part imply a lasting influence upon the nutrition, minute or integral, of the body (molecular, chemical, or histological modifications). As a result of his observations upon the curative effects of galvanism in states of inflammation, in contusions, extravasations, rheumatism, and neuralgia, this writer came to the conclusion that these effects were brought about, partly perhaps directly, by alteration of the molecular structure, the conditions of osmosis, &c., within the tissues themselves, and partly also by changes in the circulation and the blood supply of the parts. He has accordingly collected together many of these actions, some with which we are practically acquainted and others which are only hypothetically assumed in explanation of undoubted phenomena, and to these, under the name of *catalytic actions*, he has attributed the most important of the therapeutical results in the majority of cases.

It must be admitted that the idea of these catalytic actions is vague and insufficiently established. But the term is useful and corresponds to a reality which cannot be overlooked. It provides us with a short and convenient expression for a class of causes which are certainly ill defined, and it commits us to no kind of prejudice concerning their nature. It seems well that I should address a few words to you upon the subject.

Under this heading Remak included in the first place *the dilatation of the blood vessels and lymphatics*, and the consequent impulse to the circulation produced by the passage of an electric current; *the increased power of absorption* conferred upon the tissues; *the promotion of osmotic processes*, and, as an effect of the latter two causes, the increase of tissue bulk, especially in muscles. With these may be enumerated the influence *upon molecular interchange and nutrition* effected by exciting or soothing the nerves directly or through the parts which they supply; changes in the *molecular arrangement* of vital structures, and in their nutritive activity, due to the phenomena of electrolysis; and finally the consequences of the *mechanical transference of fluids* from one pole to the other.

Remak has bestowed much pains upon the study of this subject. He has seen the effects alluded to produced not merely in the parts immediately submitted to the action of the current, but also in others more remote when the nerve trunks which supplied them were galvanised. He distinguishes these as *indirect effects*. This *indirect catalysis* has been made the subject of further researches; and indeed it has become the point of departure for galvanisation of the sympathetic, of which we have heard so much and of which I also shall have a good deal to say by-and-by.

But if we enquire, as we are principally concerned to do here, into the precise physiological or experimental basis of these catalytic effects, we are compelled to admit that it is extremely insufficient. Their real existence has been recognised by nearly every electrical physician, and it is supported by the testimony of a long series of observations and experiments in disease, of which you will learn something as we proceed. But the circumstances attending these observations have usually been so complicated as to render an exact analysis of their constituent factors impossible to obtain. This has yet to be effected by means of closer physiological investigations, directed separately to each one of the elements of the so called catalytic action. Meanwhile some little progress has been made to such an end, and it is all the more desirable that the entire subject should be submitted to a systematical investigation.

Remak himself has led the way. He has shown that a very great determination of blood takes place in the muscles of the frog when galvanised with labile currents. He observed that the muscles became fuller and somewhat swollen, and he thought that they absorbed water more readily than others which had not been galvanised. This muscular enlargement under the influence of the current has also been witnessed in man, and has frequently too been described by Remak.

In addition to this may be mentioned the changes in the skin under galvanism, to which attention has been called by Remak, Bollinger, von Ziemssen, and myself. These are constantly present, and they are so obvious and so marked that I regard them as the most conclusive evidence in favour of these catalytic effects.

But of special importance in this connection is the demonstration of the *vasomotor influence* of the current, however obscure this may be in its nature and mode of action. The experiments of Przewosky are particularly noteworthy as bearing upon indirect catalysis and the vascular changes proceeding from the agency of the nerve trunks. The only question is whether they were sufficiently guarded from the risks of fallacy. Of still greater weight are those already alluded to in which Grützner and I investigated the vasodilator effects of current duration when a nerve trunk is galvanised. Finally, the recent observations of Löwenfeld concerning the contraction and dilatation of the cerebral vessels in galvanisation of the head with transverse and longitudinal currents are not without significance here.

As a further illustration may be adduced the *vascular reflexes*, to which so much attention has been paid of late, the changes in the circulation produced by acting upon the sensory nerves, and the obvious dilatation of the vessels and increased activity of the circulation in muscles when the motor nerves are excited. The production of heat in the faradised muscle of the human subject, which von Ziemssen has pointed out, may be taken as an index of increased molecular change, but it is an effect of the contractions and not directly of the current.

With these may be included the more delicate phenomena of electrolysis which physiologists have discovered in the tissues, where distinct portions of the organism approach each other, and which are ascribed to what is called *internal polarisation*. These have acquired a new value from the experiments of Drechsel, who succeeded in forming urea by electrolysis, as already stated. Mention should also be made of the important service done by Munk in establishing the existence of a cataphoric process within the living body.

Finally, but with some diffidence, may be adduced the nstance of the *trophic nerves*—those channels of nutrition so often invoked for many purposes, and so often treated as llusory, but the existence of which in one case at all events must be regarded as sufficiently established. The determination by Heidenhain of the presence of trophic fibres independently of the secretory nerves in salivary glands is assuredly a fact of he highest import in physiology. Clinical observation and physiological experiment alike point to the conclusion that here are separate trophic centres and fibres for other tissues oo, although the resources of anatomy and physiology have ot yet sufficed to distinguish them. This is true especially f the motor nerves and muscles, with which we are so much oncerned, and of the skin, the bones, and the joints. That hese trophic fibres can be affected by electricity is shown onclusively by Heidenhain's experiments, and the supposition orces itself upon us that the influence of the current upon these nutritive channels is powerful to effect vital changes of the catalytic class in the tissues and organs over which they preside. As yet, however, such a proposition, though warranted by facts, is purely hypothetical. A passing statement is all that it demands, and we have to wait for the result of further physiological research in this direction.

You see then, gentlemen, that in the period which has elapsed since Remak first cast a penetrating glance upon these matters much of the material has been gathered with which posterity is to complete the edifice of our knowledge concerning what to-day we term—not very happily perhaps, but conveniently enough—the 'catalytic effects' of electricity. When this is done we shall acquire a perception of many things of which we are now ignorant, and electrotherapeutics will have been established upon a wider scientific basis than it has at present.

FOURTH SECTION.

METHODS OF ELECTRICAL INVESTIGATION AND ELECTRODIAGNOSIS.

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LECTURE VIII.

Methods of Electrical Exploration—Exploration of Motor Nerves and Muscles—The Polar Method—General Rules—Method for the Investigation of Quantitative Excitability with the Faradic and Galvanic Currents—Method for the Investigation of Qualitative Excitability—Exploration of the Eye—Exploration of the Auditory Apparatus—Galvanic Exploration of the Sense of Taste—Investigation of Electrocutaneous Sensibility—Electromuscular Sensibility.

In the next lecture we shall speak more precisely of the diagnostic and pathological importance of the different parts of the nervous system, and of the muscles, and you will become aware of the use of a precise electrical exploration. Much of the progress of neuropathology is closely allied to electrotherapeutics and to the results obtained by its means, and we may hope that future studies and researches will throw still further light on the subject.

But this depends to a great extent upon the methods of investigation; none but exact and conscientious methods, practised with care and after the elimination of errors, can give positive results and enable us to discover almost imperceptible modifications. Unfortunately, strict investigatious are not everywhere carried out, and consequently many inaccurate and uncertain data are to be found in the literature of the subject. Their importance compels me to enter into some details concerning the methods in use.

First we have to consider the exploration of motor nerves and muscles. We have to do here with a measured and graduated excitation of limited parts of the body, usually near the surface, such as nerve trunks and branches and muscles and parts of muscles.

The principal aim of the method is to *localise* the current with requisite density and strength upon those parts, avoiding as much as possible unnecessary excitations of the neighbouring structures. The great requisite is therefore to keep before one's mind all the physical laws concerning the localisation of the current in the body and apply them to the requirements of the case.

The first consequence of these laws is that for the exploration of small parts placed in the midst of larger conducting masses, such as are nerves and muscles in the live human subject, we can utilise only the unipolar method. Of the direction of a current under such conditions there cannot be any question, as we have seen before (see Lecture V.)

The following general rules will have to be applied in the electric investigation of the body. First, we must use only one pole for each excitation; it is obvious after what we have said before that the simultaneous action of the other pole cannot be entirely excluded, but our aim is to eliminate its effects as much as possible. The electrode used for this local excitation is called the *exciting electrode* (electrode A), and we may designate the other electrode, the action of which is not observed, as the *indifferent electrode* (electrode B).

The exciting electrode must be taken as small as possible, in order to secure the greatest density of the current under it; but the smallness has certain limits, especially for the galvanic current. If the electrodes are of very small diameter the strength of the current is too much weakened thereby; besides a somewhat larger surface enables us to reach small nerves more readily than a point. Hence I always use the small or middle-size electrode for the purpose of galvanic excitations. Further, for galvanic exploration we must know accurately the conditions of current strength and resistance in the parts, and this knowledge can be secured only by using an exciting electrode of definite surface area. The most eligible, as I shall point out further on, is one of 10 square centimetres, since it affords a very convenient mathematical unit for the calculation of current strength and resistance. I shall term this the 'standard' electrode and make use of it in future in all accurate investigations.

On the other hand the indifferent electrode must be as large as possible, so as to obtain the greatest possible strength and a comparatively small density of current. This electrode should be applied to some indifferent part of the body; I prefer the sternum, which is situated in the middle line and from which the current follows similar paths and encounters similar resistances on its way to the symmetrical portions of the surface. There are in the neighbourhood no muscles or nerves, the extension of which may complicate the investigation; moreover the sternum is not sensitive, and it is convenient for the patient to hold the electrode himself. To place the latter in the hand is against the principles we have established; the nape of the neck or the lumbar region would be preferable, for the physical conditions are the same as for the sternum, but the proximity of the spinal cord and nerve roots, and the difficulty of applying the electrode, make those points less convenient. In my researches it has been my habit always to apply the electrode in the same way to the sternum. Later I shall make an exception in favour of the epigastrium.

Occasionally we may have to choose another localisation, and apply the current by means of two small electrodes placed close together. We shall come to this subject again later on. It is obviously very important to localise with the utmost certainty and accuracy the exciting electrode upon the parts we have to investigate. For this purpose anatomical knowledge and much practice in localising the current on the body, and particularly on one's own body, are necessary. It is only in this way that technical skill is to be acquired.

An important rule is always to explore according to the same method and mode of procedure. It would even be well always to use the same apparatus when experiments are made for scientific purposes, and with a view to establish comparative results. The data obtained from different instruments often cannot be used for quantitative determination; galvanometers, unless graduated accurately in absolute units, differ from one another. Small differences in the size and position of the electrode also give rise to considerable variations. Hence the results obtained by different observers are rarely comparable, and there is even no proof of their exactitude beyond the assertion of the individual experimenter.

Each observer must practise so as to secure great steadiness and dexterity in the manipulation of his own apparatus and accuracy in the interpretation of his results; it is thus only that his judgment will offer such guarantees as to deserve confidence. The task is not so easy as one would think at first sight. Much practice, technical dexterity, and experience are required for an electrical investigation which is to carry weight where slight modifications are involved.

It is well always to begin with the examination of healthy parts, especially when there is one side of the body only diseased, so as to obtain a standard of comparison, without which slight alterations may readily be overlooked and considerable errors introduced.

Electrical diagnosis depends partly upon *quantitative*, partly upon *qualitative*, changes in the excitabilities.

METHOD FOR THE QUANTITATIVE EXAMINATION OF NERVE AND MUSCLE EXCITABILITIES.

Both kinds of currents may be used. With reference to the faradic exploration, one method consists in finding the distance between the coils at which a minimum contraction of the muscles occurs, or comparing the amount of contraction obtained with a certain strength of current on symmetrical portions of the body.

This method would be correct if the terms of comparison were certain—that is to say, if the distance between the coils alone was variable among the other factors of the experiment—but this condition obtains only in unilateral disease and when symmetrical parts can be compared in the same person. Here we may assume that the anatomical and physical relations are usually the same on both sides, so that differences in the matter of contractions may be ascribed to corresponding differences of excitability; but this is not always certain and in cases of special importance an accurate estimation of the facts is necessary.

This method, however, is quite uncertain when the disease affects both sides, and the comparison must be made between the patient and other persons, for, as we have seen, different individuals vary greatly as to the resistance of their tissues to electricity (see Lecture IV.)

We must adopt the principle that the resistance is always to be tested along with the excitability. It is only after the resistance has been shown to be equal that comparable results can be obtained as to the differences which may exist in the electrical excitability.

In order to eliminate the necessity of comparison with other individuals, and find a standard of comparison on the same person, I have tried a wider method of exploration. It consists in determining the excitability of nerves in different regions of the body, and afterwards comparing the results and fixing the relative value in healthy individuals. We find a fairly constant correlation between the four pairs of nerves we have chosen for examination, so that too considerable deviations of one of them with reference to the relative value may be considered as pathological.

We are thus enabled, in cases where, for instance, both legs or both arms are diseased, to discover alterations by examination of the patient only.

To this end also we had to determine the electrical resistance of the various parts explored, and here again was found a pretty constant agreement between the relative resistances in healthy persons; it is only when resistances bear to each other normal relations that the relative degree of excitability can be properly determined.

Irregularities among relative resistances must diminish or augment the value assigned to the excitability under investigation. If, for instance, the two peroneal nerves respond to weaker currents than those indicated by the normal formula, we should conclude that their excitability is augmented, and this conclusion will be correct if the resistance at the knee is normal; if, on the other hand, it is greater our conclusion will be confirmed. On the contrary it will become doubtful if the resistance is less than normal. We must apply the same mode of reasoning to all our investigations. Where the apparent resistance varies with the distance between the coils our conclusions as to the excitability are confirmed. Where this relation is reversed they are less secure or entirely worthless.

In a case I published some years ago the following result was obtained with the faradic test:—

			Deflection of Needle : 12 cells	
Frontal nerve	r. 52 mm.	l. 50 mm.	r. 24°	
Accessory „	r. 67 „	l. 66 „	r. 28°	
Ulnar „	r. 57 „	l. 60 „	r. 6°	l. 6°
Peroneal „	r. 80 „	l. 73 „	r. 32°	l. 28°

If we did not take into account the resistance we should admit here a great increase in the excitability of the peroneal nerves, but in presence of the small resistance in the popliteal space we must have assumed, on the contrary, a diminution of faradic excitability. This was what was shown in the case by the galvanic exploration, which gave the following results:—

		Deflection
Ulnar nerve	First KCC at about	2°–3°
	„ KD „	35°–36°
Peroneal nerves	„ KCC „	17°–23°
	„ KD „	41°–45°

Hence the following method: In testing we must always choose these four nerves: the frontal nerve or branch of the facial nerve supplying the frontal muscle, the accessory nerve (see fig. 28), the ulnar nerve at the elbow, and the peroneal nerve (see fig. 33). On each of these nerves we must determine with great care with a fine electrode, on the most excitable spot, the distance of the coils at which the minimum contraction occurs. This is done by marking the number at which weak but visible contraction is obtained with the negative pole of the secondary coil.

Then by means of the galvanic current and with a middle-size electrode, moistened with hot water every time it is applied, the galvanometric deviation is determined with a definite number of cells (ten or twelve). The positive pole remains fixed upon the sternum and the negative is applied to all the spots at which the excitation is made. The numbers thus found are likewise tabulated.

We thus obtain two series of numbers, the one representing the relative faradic excitability of the four nerves, the other the relative state of the resistance at the corresponding points on each side of the body. I have already pointed out how the results of the second series assist the conclusions to be drawn from the first. There is, as a rule, a pretty constant proportion between the two series in healthy individuals living under similar conditions. Here are two examples taken in healthy persons :—

—	Distance in Mm. of Coils for Minimum Contraction		Deflection of Galvanometer with 10 Cells : 150° Resistance	
I. *Healthy Man, aged* 38 (*Heidelberg*), *Labourer :*				
Frontal nerve	r. 165	l. 166	r. 18°	l. 19°
Accessory ,, ...	r. 172	l. 177	r. 16°	l. 15°
Ulnar ,, ...	r. 159	l. 158	r. 6°	l. 6°
Peroneal ,, ...	r. 160	l. 163	r. 7°	l. 9°
II. *Healthy Man, aged* 24 (*Leipzig*), *Labourer :*				
Frontal nerve	r. 195	l. 192	r. 17°	l. 17°
Accessory ,, ...	r. 187	l. 182	r. 10°	l. 9°
Ulnar ,, ...	r. 175	l. 185	r. 6°	l. 10°
Peroneal ,, ...	r. 180	l. 180	r. 5°	l. 5°

These tables can be used with my own apparatus only. With other instruments the numbers may vary, but their relations remain the same; hence each observer must draw up his own tables with his own apparatus.

From these tables and many others which I have framed from the experience of years we learn, as the first consequence, that the numbers obtained for either side of the body coincide almost exactly. An occasional discrepancy of 10 millimetres is the most we find, and I may remark by the way that we have here an admirable test for the accuracy of our conclusions in the exploration of unsymmetrical disease. Further, all four pairs of nerves are excited by minimum currents of sufficiently comparable strength, the difference in various situations rarely exceeding 20 to 25 millimetres. The relation between the ulnars and peroneals in this respect is of special import; they require almost equal distances of coils, while the frontals often respond only to a distance slightly less and the accessories to one a little greater.

As regards resistance, somewhat different relations obtain. Whereas in the regions of the ulnars and peronei the deviation of the needle is nearly the same, a greater takes place in the case of the accessories, and in the frontals a greater still. In these last the resistance is least. Variations in this respect, especially in the regions last named, are more common than those affecting the distance of the coils. The two series of numbers, therefore, do not correspond. The greatest distances of coil and the greatest deviation of the needle are not present together. It is clear that the differing resistance of the skin is not the only source of variation here. But, since the two series are comparable in healthy persons, we can draw from them certain conclusions. Amongst women and children there is exhibited so much variety, on account of the variable development of the *panniculus adiposus*, that I conceive it to be impossible to construct a serviceable formula in their case. The data given above hold only for healthy men of the working class and of middle age.

It is true that this course has its drawbacks; certain defects and fallacies may attend it; but so far as I know it is the best at present open to us. At any rate it is only by its aid that we can determine very slight quantitative variations sufficiently accurately to satisfy the requirements of science, while many things will still certainly escape our notice on account of unfavourable anatomical conditions.

I think it well to direct your attention here to some of the difficulties and sources of error which you may have to encounter. In the first place you must find the situation where the nerve is most excitable, and then determine the weakest current that will excite it. Much skill and patience are required for this. It is wonderful to see how slight a movement of the exciting electrode will produce a wholly different effect. In doubtful cases you should always seek to confirm the results obtained. Special difficulties of this kind arise in connection with the ulnar and peroneal nerves. The situation in which the former is most excitable is about 3 centimetres above the internal condyle, at the inner border of the triceps; in the case of the peroneal it is 3 or 4 centimetres above the head of the fibula, beside the tendon of the biceps, and can be reached with the electrode only after much searching. The position of the limbs is important. It is my custom to extend the legs and arms, and in this way the nerves appear to me to be more accessible. The minimum excitation too may easily escape notice. The muscles under examination should be carefully maintained lax, and close attention is required. Another source of error with which I had to contend is this: Given a patient whose skin is tender, if you have to search long with a fine electrode for the peroneal nerve in the popliteal space it may happen that an abrasion of the epidermis at one spot occurs, and the resistance greatly lessens in consequence. In this event weaker currents, and often such as are extremely feeble, will give rise to contractions. These must not be taken as an expression of excitability.

When our purpose is a faradic examination of certain nerves and muscles, and not a general exploration, it is effected by a careful comparison with the healthy side, or the same part in healthy individuals. The precautions to be taken are those already detailed. You should be very guarded in your conclusions, for here the most experienced observer may be deceived. Hence the expediency of repeated investigations, especially in important and obscure cases. And I would recommend you to make it a rule to confine yourselves to *probable* conclusions when there is a slight variation in your results.

The same principles should regulate the use of the *qantitative examination of galvanic excitability*, and here even greater caution is required. The plan formerly in vogue of recording the number of elements used or the resistances of a rheostat in circuit as a measure of current strength, will serve only to a certain extent for comparing the two sides of the body, and is altogether useless for comparison between individuals. The difference in the specific resistance to be met with in different subjects (see Lecture IV.), and the transient variations of resistance due to the action of the current itself, vitiate the conclusions of former researches, my own amongst them, in which this factor was overlooked. Except for very great differences nothing positive can be asserted in this way.

The first thing to be done, when it is a question of very small differences, is to examine with the same density of current the different nerves and muscles under investigation. The stimulus should then be equal in symmetrical nerves, and a discrepancy in contraction indicates a difference of excitability. This condition is easily secured, at all events approximately. Current density depends on the one hand on the size and surface area of the electrodes, and on the other on the total strength of the current. These must be known; and they afford data for an expression of the density of the current in use.

It is essential to use always the same electrodes in performing the investigation; and it seems to me on this account very desirable that, for the purpose of quantitative examination by galvanism, a standard electrode should be adopted, of definite area, and used by all observers. This is the only way to obtain comparable results. To my mind such an electrode should be of 10 square centimetres surface area, whether round or square. Apart from its convenient size it will provide a very simple system of notation for current strength and density. We may either express the absolute strength only in ma. (either expressing or assuming as known the size of the standard electrode), thus, '1, 3, or 5 ma. (with standard electrode),' or we may give, instead of the ordinary fraction indicating the density, a decimal fraction; thus instead of $\frac{1}{10}$, $\frac{1\cdot5}{10}$, $\frac{3}{10}$ we may say that excitation occurs at 0·1, 0·15, 0·3 absolute density. In this way we obtain a simple and uniform mode of expressing results of a definite value for all observers.

By adopting such a 'standard electrode' we can be sure that with a given current strength (or deviation of the needle) a certain resistance is present at the point of application of the exciting electrode. But this is not enough. We must have the same current density in the nerve which is at a greater or less distance from the surface. It is necessary, then, to apply the exciting electrode to the parts to be compared exactly in the same manner, under the same anatomical conditions, and with the same pressure, so that its relations with the nerve as to distance and other circumstances shall be in each case as nearly as possible the same.

It is only when these three conditions are fulfilled that we can make any positive assertion. When the same electrodes are used in the same way, and the same deviation of the needle is produced, we can rest satisfied that in the symmetrical nerves to be compared there is the same current density. Where the first two of these conditions are secured we can infer the density from the deviation. Hence we can make use of the deviation for the perception and measurement of excitability in the nerve, and we can determine its degree when a contraction of certain force, either the minimum or tetanic, takes place. We may, therefore, regard the deviation of the needle in the case of symmetrical nerves as an expression of their excitability.

I need not repeat that the deviation of the needle as a measure of the absolute current strength can never be replaced by a knowledge of the number of elements used, or of the rheostatic resistance interposed. The principle of this method is to make use of currents of known density in the investigation of similar parts, and this entails the use of the galvanometer. Even with this precaution there are many sources of fallacy which can be but partially avoided by the most experienced observers. It is not enough to know the total strength of the current. What concerns us is the strength of that part of it within the nerves to be examined (current density *in the nerves*), and this is influenced by many circumstances, as the depth of the fatty layer, the thickness of the skin, and varying anatomical conditions. On the other hand I must dissent from von Ziemssen, who has lately laid much stress upon the resistance of the epidermis, its state of moisture, &c. Given the current strength in the entire circuit, it is quite immaterial whether the resistance is greater or less at a particular part. So far as it concerns us it has already been indicated by the needle. The important point is that there shall be a current of a definite strength within the body, and it is precisely the advantage of the system of absolute measurement that it enables us to evade the formidable difficulties of taking into account the separate factors—such as the number of cells, the condition of the epidermis, the wetness of the electrodes, temperature, and the rest.

I learnt from a very instructive case of ulnar neuritis the reality of the sources of error alluded to above. The nerve of the right side was nearer the surface than normally, in consequence of a former dislocation of the elbow. Until the true cause appeared, the faradic or galvanic current needed to excite the nerve was so evidently less than that for the other side as to point to a very great pathological increase of excitability. (Compare Vierordt, *op. cit.*)

Even with every precaution, however, this method will give reliable results only in cases of very great changes. Smaller differences can be but *probably* affirmed. Still it is the only one open to us in these cases.

Its object is to determine the current strength which causes the earliest KCC in a particular nerve or muscle, and then that strength which produces the first KD reaction or KDT.

On account of the inconstancy of the resistance arising from the action of the current, and perhaps from causes within the nerve, it is quite essential to proceed in the same way, and with a current precisely similar as to duration and otherwise, on both sides of the body, and hence it is well to adopt a definite mode of procedure. Place the large 'indifferent' electrode upon the sternum, the exciting 'standard' electrode accurately over the nerve or muscle to be examined. Then determine at first without a galvanometer, and using only a few cells, the point at which contraction first occurs with the kathodic closure, testing each time with three rapid closures. When the first feeble contraction is obtained interpose the galvanometer[1] and ascertain the deviation for the number of cells you have employed. The absolute strength (in ma.) thus determined is to be recorded.

Now increase the current, and with each increase effect three kathodic closures until that strength is reached at which the KCC, short and quick as lightning, changes into a persistent KD (tet.), which disappears as rapidly. So you get KDT. It is to determine this point that the deviation of the needle is noted and recorded. There is no need as a rule to take the number of cells into account. In this way you arrive at the following figures, for example: [1]

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[1] The new galvanometer, in which the oscillation of the needle has been reduced to a minimum, may be allowed to remain intercalated during the kathodic closures, and in this way the observation is performed more quickly.

Ulnar nerve:				
First KCC with	5° defl. or	0·5 ma.	= 0·05 abs. D.
„ KD >	„ 26° „	9 „	= 0·9 „
Radial nerve:				
First KCC with	6° defl. or	1 ma.	= 0·1 abs. D.
„ KD >	„ 28° „	9 „	= 0·9 „

With healthy and symmetrical nerves in the same person small differences of excitability can be appreciated.[2] The matter is not so easy when we institute a comparison between healthy individuals. But here, too, the use of definite and accurately determined current strengths is an additional safeguard. In point of fact it has been shown by accurate investigations that for the most part superficial nerves exhibit the first KCC with current strengths of from 0·5 to 2 ma. ('standard' electrode) and from 0·05 to 0·2 absolute density: the first KCT with 4 to 10 ma. and 0·4 to 1 absolute density.[3] Further investigations with the standard electrode are needed to establish these conclusions as a physiological basis for the estimation of excitability.

To obviate the errors to which we are always exposed in drawing conclusions from one individual to another, we may here also determine the condition of excitability of the four pairs of nerves in health, with a view to ascertaining their *relative* expressions, and applying this knowledge to the study of disease. Proceeding as before, the needle deflection corresponding to the minimal contraction and tetanus are noted; and the accompanying table, for instance, may be derived.

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[1] I give the numbers obtained with the old galvanometers, and expressing the deflection of the needle, before the absolute graduation was adopted. In the last column is also indicated the absolute current density derived with the standard electrode.

[2] This may also be done with great accuracy by adopting Brenner's contrivance. He excited the two symmetrical nerves together by means of a divided electrode, and compared the resulting contractions directly at each opening and closure of the circuit. In this way the physical conditions are practically the same. The resistance, however, requires to be determined separately.

[3] The galvanometer which I originally used gave 2° to 12° deflection for the first KCC, 25° to 35° for the first KD. Observers who cannot obtain an absolute galvanometer must correct these numbers for their own instrument, since they differ somewhat in each.

Note.—1 was obtained with the old galvanometer, 2 with the unit galvanometer and 'standard' electrode.

Healthy Males, 38 and 24 years of age.

Nerves		Appearance of First KCC		Appearance of First KD	
		1. Old Method	2. New Method	1. Old Method	2. New Method
Frontal	right	8 cells, 16°	1·4 ma.	12 cells, 32°	8·0 ma.
	left	6 " 18°	1·2 "	10 " 29°	8·0 "
Sp. access.	right	6 " 7°	0·5 "	12 " 29°	4·0 "
	left	6 " 8°	0·5 "	12 " 31°	4·0 "
Ulnar	right	6 " 5°	0·4 "	14 " 28°	6·0 "
	left	6 " 5°	0·4 "	14 " 27°	5·5 "
Peroneal	right	8 " 7°	1·5 "	14 " 29°	7·0 "
	left	8 " 8°	1·5 "	12 " 28°	7·0 "

These preliminary data can be derived from a comparison of healthy individuals of middle age, although it must be admitted that great discrepancies sometimes occur. The frontal nerve is especially open to them; and perhaps it is well to omit it in an examination of this kind, both for this reason and also because it is not always easy to induce in it the kathodic duration tetanus. On the other hand the remaining pairs will be found to exhibit pretty constant relations. This is especially true of the ulnars and peronei, for which the figures are almost identical, the first KCC occurring before 2 ma. are reached, and the first KD tetanus with from 5 to 8 ma. The difference of from 4 to 6 ma. between KCC and KD is also fairly constant; so that the determination of KD furnishes a good index of galvanic excitability. In the same way you can conduct the enquiry with the other exciting agents, and determine with what current strength the anodic closure and opening, and the kathodic opening contractions first occur. I would refer you to a table (Lect. V.) in which I have already set forth the results of such an examination.

What I have said concerning the faradic quantitative exploration holds true for the galvanic investigation. The latter presents many difficulties and is exposed to many errors—very often it yields no satisfactory results. Still it is the best method at our disposal. It affords at all events some useful and, to a certain extent, reliable data. The same precautions are indicated, and practice is equally indispensable.

To thoroughly investigate, according to the methods described, the condition of galvanic and faradic excitability would occupy an experienced observer some half or three-quarters of an hour; and when you have done so you will have some idea of its quantitative characteristics throughout the nervous system. You can then investigate the condition of the muscles; but, for the present, that is of secondary importance.

It is, however, of the utmost consequence to determine the mode of contraction with reference to any unusual phenomena it may exhibit.

I will add a few words upon this subject.

THE METHOD OF DETERMINING THE QUALITATIVE EXCITABILITY OF NERVES AND MUSCLES.

We have not yet applied the faradic current to this purpose. On the other hand, the qualitative investigation by galvanism is one of the greatest importance, especially for muscles; since departures from the law of contraction and its phenomena play a leading part in electro-diagnosis. Here we have to establish the law of contraction for each individual nerve and muscle; to see if the contractions occur in their regular order and with their usual force; and to determine whether they are normal in their form, duration, and course. We must employ the method which has been used for ascertaining the law of contractions—that is, the polar method—and in doing so we must adopt all the precautions detailed above. Here again is needed much practice and skill in the use of the apparatus. You must be familiar with each nerve and its peculiarities—I have already called your attention to this point. With reference to the muscles it is especially important to investigate their mode of contraction, its rapid or more gradual development, the greater efficiency of one or the other form of stimulus. In every doubtful case it is well to institute a comparison with the same muscles in healthy persons.

To obtain more accurate details in reference to atrophied muscles or nerves of impaired excitability, it is sometimes necessary to resort to special methods, so as to eliminate involuntary and misleading movements and to determine as accurately as possible the effect of the current required. These methods are suggested by physical considerations, and I will revert to the subject again.

We pass now to the

METHOD OF ELECTRICAL EXPLORATION OF THE EYE,

which Brenner has brought to a system of great perfection. Here too we proceed by the polar method, applying the 'exciting' (medium or small) or better still the 'standard' electrode on the closed lids, temple, or forehead, while the larger indifferent electrode closes the circuit at the sternum. I have also thought that the optical and galvanic perception was helped by applying the indifferent electrode to the nape of the neck. This, therefore, is admissible. You then proceed to examine each eye with the anodic and kathodic opening and closure. The current need not be strong. Six or eight cells usually suffice (0·3–1·0–1·5 ma.)

This exploration is often difficult, depending as it does upon the subjective perception of light and colour, but it can be effected by patient attention and proper instructions to the person operated upon. It is a great help to conduct it in a feebly lighted room, and of course the eyes must always be closed.

On account of the great excitability of the retina, it is often hard to eliminate the effects communicated to the other eye. In such a case you must not place the indifferent electrode at the sternum, but, employing a 'small' one, apply it to the temple of the same side as the eye under examination. Then the other which is also 'small' is placed upon the closed lids.

METHOD OF EXPLORING THE EAR.

This has also been reduced to a system by the efforts of Brenner. In the first instance he induced as well-defined and concentrated a current as he could obtain within the ear and directed to the auditory nerves; and with this object he introduced the exciting electrode, of one form or another, within the external meatus, filled with water or a saline solution, and partly protected by little funnels of glass or india-rubber, or by caps of sponge. Ritter applied a wire conductor, and thus used currents of great strength. But we are indebted to Brenner for the further application of the polar method to the ear, and for perfecting a system of exploration which commends itself alike on clinical and scientific grounds. This I have already described to you. The introduction of the exciting electrode within the auditory meatus, however, makes the operation extremely painful and almost intolerable. On the other hand to fill the meatus with water is a cause of misleading sounds, which add to the intrinsic difficulties of the process.

For these reasons I have adopted a somewhat different process, employing an exciting electrode of 'medium' size or the 'standard' electrode, well moistened and placing it a little in front of the ear, so as to overlie the tragus without completely covering the external meatus. This process has been used extensively for 'external exploration.' The indifferent electrode may be used at the sternum or the opposite hand, best of all at the nape of the neck; here there is slight resistance, and currents of great density can be obtained. I have already told you the details to follow: kathodic closures with accumulating currents, occasional investigation with other modes of excitation, and reversing the poles in cases of unusual difficulty.

Coolness, patience, and much practice are needed for success, and many sittings may be required to educate the patient. Feeble currents are best in the first instance and they may be gradually increased. The previous induction of AD reaction is a help to producing a KCC. Then the more rapid the alternation of anodic opening and kathodic closure, and the changes effected by the commutator, the quicker and more energetic will be the kathodic closure reaction. A prolonged closure facilitates the production of the anodic opening reaction. But the best way to obtain the latter is to pass by slow increase to the strongest current that can be borne, during the continuance of KD, and then suddenly break the circuit.

The examination of patients with diseases of the ear is usually attended with little difficulty.

METHOD OF EXPLORATION FOR TASTE.

To test the sense of taste with galvanism you can apply the poles, one to either cheek, so as to pass a current across the buccal cavity, and compare your sensations on either side with the account given by the patient of his, when similarly treated. For more accurately localised investigations the polar method may be employed. Apply to different parts of the tongue, throat, and cheeks a small sponge electrode of appropriate shape and furnished with an interruptor. With this investigate the effects of KC and KD, AC and AD.

Another excellent method has been introduced by Neumann for a minute investigation of the sense of taste. The two poles are isolated by means of a catheter or glass cylinder, from which, however, their metallic extremities project at a distance from each other of two or three millimetres. Supplied by one or two cells this double electrode is admirably adapted to develop the galvanic taste in limited areas. Placed on the tongue there is a sensation of heat accompanied by a marked saline, acid, or metallic taste. The patient should be prepared for this. By this means the sensitive areas are accurately defined, and pathological differences between the two sides of the tongue determined.

ELECTRICAL EXAMINATION OF CUTANEOUS SENSIBILITY.

It was natural that electricity should be applied to this purpose; but it has not been uniformly recognised that it can be made to exhibit here two distinct classes of phenomena: first, the excitability of the nerves of the skin and their terminal organs, as we demonstrate it of the motor nerves (this is, therefore, analogous to the phenomena of contraction); and secondly, the special effect of electricity upon the skin as an organ of sense. The question arises here whether we have any right to assume electricity as the test of absolute sensibility, or the measure of its modifications. There are serious objections to such an assumption. As an organ of sense the skin must be studied in reference to appropriate excitants only. Now these are touch, pressure, heat, and cold, and the modifications of these which are capable of causing pain. The claims of electricity to a position among these appropriate excitants is open to exception. We would not think of using it as a test of acuteness of vision or for the sensations of light and colour; but it does afford valuable information as to the condition of electrical excitability in the visual nervous organs. Similarly, while it cannot be employed as an index of cutaneous sensibility in general, it can be taken to represent a special and determinate form of this, which it is useful to study in connection with various diseases. And whereas in the eye we cannot by its use decide whether a person is blind or not, we can here affirm the presence or absence, at least, of one kind of sensibility. There is no need here to call your attention to the important experiments in which the electric current was first made to demonstrate the presence of extensive anæsthesia and analgesia, and to expose malingering and hysteria. The methods employed suggest themselves. The electrodes may be moist or dry, and the currents pretty strong. The faradic brush is a useful resource.

I have already alluded to the necessity of investigating the faradic and galvanic excitability of the cutaneous nerves and their terminations, so as to ascertain especially the galvanic reaction of sensory nerves (Lecture VI.) The same methods must be employed as for the exploration of motor nerves.

In dealing with less evident derangements of sensibility, the endeavour to employ the faradic current as a measure capable of being expressed in figures has not yet been attended with great success.

Leyden was the first to make an attempt in this direction. He used a pair of blunted compass points one centimetre apart to introduce a secondary faradic current, and recorded the distance of the coils when a minimum sensation was produced. This distance at several parts of the skin yielded a series of numbers, from which he concluded that normal sensibility at the surface was pretty uniform throughout the body, although the use of a strong sledge instrument showed a difference of 70 to 76 millimetres between the sole and dorsum of the foot in two series of experiments. The resistance is in no case considered.

Bernhardt has performed these experiments for himself, and he has applied them to determine the point of pain under faradic excitation. In this way he obtained results analogous to those of Leyden, and arranged them in a table for practical use. He also has omitted to take resistance into account.

I have made many efforts of the kind, but without obtaining figures nearly so accurate or consistent as those of Leyden. This I attribute to sources of fallacy inherent in the method. The current conveyed by the compass points can enter at two spots only, and when these are two different poles they have a different exciting power. It is true that this can be remedied by adopting the ingenious suggestion of Brenner, of connecting the two points with the same electrode, and applying the other as 'indifferent.' Nothing certainly is gained by using two points instead of one in this case, unless with reference to Weber's zones of touch. A consideration of the anatomy of the skin and the usual course of the current will suffice to show that the use of only two points is exposed to many sources of fallacy, even in symmetrical parts of the skin. Should one impinge upon the branch of a nerve the effect will be quite different from that produced at an adjacent spot. Slight moisture or free perspiration would also lead to misconceptions. And finally, to overlook the consideration of resistance to the current is to introduce a third element, which vitiates alike conclusions made in comparing different parts and the same parts in different individuals. Hence I have long since abandoned this method, which can only lead to the loss of time.

I have met with as little success in the employment of the method subsequently suggested by Bernhardt for the investigation of sensibility to pain by means of the galvanic current. He employs a metallic brush carrying the negative pole, the positive being held in the left hand. With thirty cells he places a rheostat in a parallel circuit at zero. Then he increases the resistance in the rheostat until pain occurs at the point of application of the electrode. The figures expressing these resistances form a table which is supposed to represent the minimum differences among different individuals. I have not been able to convince myself of this. The sensations produced are extremely unpleasant. The currents required are of very inconstant strength, and often also different in character at corresponding points, on account, no doubt, of peculiarities in the resistance of the epidermis. I fail to see the practical advantages of the procedure, which has the further fault that it attempts to determine the active force of the current by means of the galvanometer; while in fact a lively sense of pain is evinced with the slightest excitation. Bernhardt himself found this with a declination of 1° to $2\frac{1}{2}°$.

Thus I am compelled to seek for some more practical and useful method of investigation for farado-cutaneous sensibility. Such a one is that of Drosdoff; but it, too, is far from perfect.

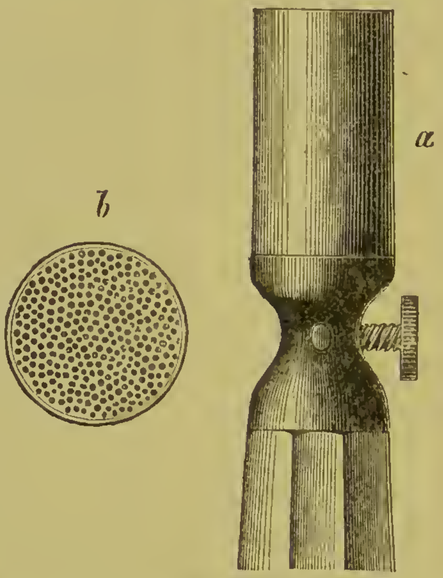


Fig. 20.—Electrode for the investigation of farado-cutaneous sensibility. *a*, vulcanite case; *b*, free extremity of electrode.

I have not adopted the soft metallic brush with a flat surface which he has recommended for the exciting electrode in conjunction with the indifferent electrode at the sternum; but I have had made for me by Messrs. Stöhrer and Son, of Leipzig, a special electrode, which, like the brush, offers several points of entry to the current, while it avoids the disadvantage of the mechanical effect caused by the distinct iron wires in the latter. A bundle of over 400 metallic wires, sheathed and varnished, is firmly enclosed in a vulcanite case of about 2 centimetres diameter, securely soldered at one end to the rheophore in an electrode handle, and at the other, which is free, highly polished, so that when applied to the skin it has the effect of a smooth metallic surface. It covers a circular area of skin of about 2 centimetres in diameter, and into this the current enters in more than 400 parts. In this way the sources of error arising from perspiration, hair follicles, smaller nerves, &c., are as far as possible eliminated. Instead of two points of entry there are 400, and a more regular action upon the numerous nerve terminations is secured. As an exciting electrode I have found this a practical and satisfactory arrangement. It is connected with the negative pole of the opening current and placed firmly upon some part of the skin. Then by gently moving the coils the points are determined at which occur the minimum electrical sensation, and that of tickling and pricking. These are accurately ascertained by frequently opening and closing the circuit. Here it is well to moisten the skin somewhat, by friction with a wet towel.

Next the coil is moved more quickly until the patient complains of marked pain. The distance now is also recorded. Although different people have different ideas of pain, the disparity of results among healthy subjects is not found to be great.

A large number of points in different parts of the body are to be examined. I have enumerated, to save time, a series of such points, and appended the results. To these others can be added indefinitely.

Table I.—*A Man, aged* 37, *Healthy.*

Points of Excitation	Minimum Sensation		Pain		Deflection of Needle with 8 Cells and 150 Resistance
	Right	Left	Right	Left	
Cheeks	200	213	130	130	26°–27°
Neck	200	192	125	127	23°-22°
Arm (inner side)	198	202	125	130	20°–22°
Forearm (inner side)	196	185	115	120	18°–18°
Back of hand	170	180	115	105	12°–18°
Ends of fingers	115	125	85	86	2°–1°
Abdomen	195	197	125	125	21°–20°
Thigh (inner side)	195	190	130	125	23°–20°
Leg (outer side)	183	185	119	122	19°–20°
Dorsum of foot	183	181	110	125	10°–12°
Sole (middle)	110	108	75	82	5°–5°

Table II.—*A Man, aged 26, Healthy.*

Place of Excitation	Minimum Sensation		Pain		Deflection of Needle with 8 Cells and 150 Resistance
	Right	Left	Right	Left	
Cheeks	217	220	130	133	30°–30°
Neck	187	180	117	120	29°–27°
Arm (inner side) . .	195	180	110	116	20°–22°
Forearm (inner side) .	186	200	111	117	19°–16°
Back of hand	168	160	111	115	17°–18°
Ends of fingers	123	125	95	96	2°–1°
Abdomen	177	177	135	123	20°–18°
Thigh (inner side)	173	170	113	122	18°–18°
Leg (outer side)	160	178	107	109	4°–4°
Dorsum of foot	170	180	110	110	4°–4°
Sole (middle)	104	107	82	80	4°–5°

I thought it also necessary to ascertain the galvanic resistance of the skin at the same places, in order to acquaint myself with its variations, and correct the former figures accordingly. In this way a connected idea may be formed of farado-cutaneous sensibility in the body generally, and satisfactory results are arrived at for the majority of healthy subjects, which are sufficiently constant to afford a basis for pathological investigations, as I have often had occasion to verify. The entire process can be accomplished in twenty or thirty minutes. I have given above, as an illustration, two tables derived from healthy males.

The *average* figures in healthy men taken at different parts, as indicated, and resulting from numerous experiments, are as follows:—

Place of Excitation	Minimum Sensation	Pain	Deflection of the Needle, with 8 Cells and 150 Resistance
Cheek	200–220	130	26°
Neck	180–200	120	22°
Arm (inner side)	200	120	21°
Forearm (inner side) . . .	190	115	18°
Back of hand	175	110	15°
Points of fingers	125	90	2°
Abdomen	190	120	20°
Thigh (inner side)	180	115	21°
Leg (outer side)	170	110	19°
Dorsum of foot	175	110	10°
Sole	110	80	5°

These figures are tolerably consistent. They show especially that the distances between the coils are proportionate to the resistance to the current, and that the differences between the two sides of the body are inconsiderable, and very often to be traced to variation in the resistance. This simplifies very much the process of comparison in unilateral disease, and enables us to obtain very definite numbers as its expression. Thus, a case of

Paresis of Right Ulnar Nerve.

Place of Excitation	Minimum Sensation		Pain		Deflection of Needle with 8 Cells and 150 Resistance
	Right	Left	Right	Left	
Ends of fingers	114	133	88	105	2°–5°
Ulnar side of hand . . .	108	120	73	88	25°–25°

All the elements of uncertainty which this and other previous methods involved appear to be eliminated in that of Tschiriew and de Watteville, who have conceived the happy idea of removing the difficulty presented by the variable resistance in the epidermis by the simple expedient of intercalating at the exciting electrode a resistance (of 3,000,000 ohms) so great as to render the comparatively slight variations of no moment. They claim in this way to have determined the absolute faradic sensibility of the cutaneous nerves, and to have found it uniform throughout the body. Their method affords an adequate means of investigating pathological conditions. As a theory it is plausible, but it has not been shown to be practicable. To secure an electrode provided with so great a resistance, it would be necessary, I am inclined to think, to construct apparatus of much greater power than we use now, and it is still more difficult to conceive how it may be combined with the other practical requirements. For the present, therefore, we must be content to employ the less perfect methods hitherto in use.

There remain but a few words to say on the subject of the investigation of *electro-muscular sensibility*, to which, as is well known, Duchenne attributed much importance as an aid to diagnosis. Of late it has been almost entirely overlooked, and at least that it is not readily available there is no difficulty in admitting.

The examination consists in producing in separate muscles more or less energetic contractions by means of faradic currents applied to the nerve trunks or motor points, at the same time noting the occurrence of pain due to tension and compression in the muscle itself.

In consequence of the simultaneous excitation of sensory nerves and of the skin it is not always easy accurately to distinguish this sensation. It follows that the mode of exploration is simple and certain only in cases where cutaneous anæsthesia coexists, as in certain forms of hysteria.

LECTURE IX.

Pathological Modifications of Electrical Excitability, and their Use in Diagnosis—*A*, Electrical Diagnosis of Motor Nerves and Muscles—1, Increased, 2, Diminished, Electrical Excitability—3, Reaction of Degeneration—Historical Retrospect—Description—Manifestations—Increase of Mechanical Excitability.

From the moment when it was known how to apply electricity locally to various parts of the system, and in particular to the motor nerves and muscles, in such a way as to produce definite physiological effects in the living subject, it became a matter of speculation whether these processes might not have their parallels in diseased conditions and perhaps their value in diagnosis and prognosis. Before long it was noticed that both quantitative and qualitative modifications of electrical excitability were an extremely frequent characteristic of pathological states, and it is not the least of Duchenne's achievements to have systematically examined and applied them in all their bearings—though at first he did so only in reference to the faradic current. When the use of galvanism was again introduced into therapeutics many instances of variation in galvanic excitability were observed and described by R. Remak, Benedikt, and others; but it was only after the discovery and scientific determination of the 'reaction of degeneration,' and the introduction of more exact methods for the investigation of quantitative excitability that due importance was given to an accurate electrical exploration in nervous disease, and its necessity admitted as a part of every complete investigation.

We are now aware that in pathological conditions there occurs a long series of changes in electrical excitability, and from these, in many circumstances, we can draw conclusions of a highly definite character with reference to anatomical states in nerves and muscles—often, too, derive accurate information of a positive or negative kind concerning the true seat of a lesion; and, finally, they throw much light upon prognosis, to say nothing of their important influence in directing the choice of remedies. The observations which have already been made have so clearly established the great value of electricity in diagnosis that we are not justified in dispensing with it in any important case. Its applications are very numerous. But, gentlemen, you must for this very reason be careful not to overestimate its value or expect too much from its agency. In many cases of nervous disease it affords no useful information, and leaves the affection as obscure as ever. There are very many forms of disease on which the investigation we are dealing with now does not and cannot throw any light. Still in some of these we may look for better results from the application of more delicate methods.

I think it well to state to you in a systematic form the modifications with which we have become acquainted hitherto, their manifestations and the inferences which they yield.

A. MODIFICATIONS OF THE ELECTRICAL EXCITABILITY OF MOTOR NERVES AND MUSCLES.

These are the chief in importance. They are both quantitative and qualitative: the latter chiefly in the muscles and seldom without the coexistence of the former. The behaviour of the nerves and muscles to the faradic and galvanic currents respectively is in many instances similar, but in many cases, too, it is entirely different; and this occurs especially in muscles. All this will be plain to you later.

1. Increase (Exaltation) of Electrical Excitability.

In *faradic* exploration an increased excitability is shown by: the readier reaction of the nerves and muscles to the current;

the occurrence of the minimum contraction with a greater distance between the coils; or, this distance remaining the same, by the greater energy of the contraction.

Tetany.—Male, aged 22	Distance of Coils in Mm. for Minimum Contraction		Deflection of Needle with 16 Cells
	Right	Left	
Frontal nerve	147	145	12°
Spinal accessory nerve	185	187	15°
Ulnar nerve	185	182	8°
Peroneal nerve	180	190	8°

The preceding table will serve as an illustration. It is taken from a case of tetany, and may be compared with the normal figures (p. 144).

Here, then, is a remarkable increase of excitability in the three pairs: accessory, ulnar, and peroneal.

Another example of exalted excitability obtaining only in the peroneals, and taken from an early stage of tabes, may be added here.

Case of Tabes	Distance of Coils in Mm. for Minimum Contraction		Deflection of Galvanometer, 10 Cells, 150 Resistance	
	Right	Left		
Frontal nerve	170	168	24°	24°
Accessory ,, ...	166	167	17°	18°
Ulnar ,, ...	170	165	6°	6°
Peroneal ,, ...	205	200	7°	8°

The results are still plainer in cases of unilateral exaltation of excitability.

With the *galvanic* current a simple exaltation of excitability is marked by: the occurrence of KCC with a feebler current (slighter deflection); the passage of this with a slight increase into KD (tetanus); the very early appearance of a brisk AOC close upon the ACC; and finally, as an index of the highest degree of excitability, the development of AOT.

An 'increase of secondary excitability' has also been taken to indicate increased excitability. By this is meant an actual and marked modification in the nerve due to the repeated action of the current. Its reality, however, has yet to be established with reference to the determination of tissue resistance under the circumstances.

In many instances an increase of excitability is clearly shown by a remarkable disproportion between the motor and sensory reactions, when an active contraction is accompanied by a slight and painless sensation.

Under all circumstances with simply exalted excitability qualitative changes are absent.

Again, let us take for illustration the case of tetany already quoted. It must be observed, however, that the examination was made with a very faulty galvanometer.

Here was found—

In the radial nerve :
First KCC for ½° deflection (in health for 3° deflection)
First KD „ 3° „ („ „ 10° „)
Difference between KCC and KD 2½° (in health 7°) deflection

In the ulnar nerve :
First KCC for ¼° deflection (in health for 6° deflection)
First KD „ 3½° „ („ 10° to 11° „)

In the median nerve :

$$\left.\begin{array}{ll}\text{First KCC for} & \tfrac{1}{4}^\circ \\ \text{First KD} \quad ,, & 4\tfrac{1}{2}^\circ\end{array}\right\}\text{difference } 4\tfrac{1}{4}^\circ$$

Observation of the different phases of the excitation showed a rapid succession as the strength of the current increased, ending in the development of AO and AC tetanus.

In the radial :

6 cells	KCC′	AOC	
8 „	KD	AOC′	ACC
12 „	KD″	AOT	ACC′
14 „	KD″	AOT′	AD

In healthy individuals with a similar resistance to the current, AOT (tetanus) cannot be produced with 24 to 26 cells.

In conclusion, I will add here some observations made in a recent case of tetany, which was examined with the aid of a good galvanometer, and presented a notable increase of faradic and galvanic excitability. It occurred in a shoemaker named Kuntz, aged 17, who had had at somewhat long intervals serious and prolonged tetanic spasms, especially in the hands. Trousseau's symptom, increased mechanical excitability of nerves and muscles, was present. The examination was made shortly after the last attack.

Faradic Excitability.

Tetany.—Male, aged 17	Distance of Coils in Mm. for Minimum Contraction		Deflection on Galvanometer with 8 Cells, 150 Resistance	
	Right	Left		
Frontal nerve	184	188	24°	24°
Spinal accessory nerve	204	210	17°	18°
Ulnar nerve	252	233	7°	12°
Peroneal nerve	265	332(?)	4°	5°

Thus, without any change in the resistance, there was an enormous increase of faradic excitability.

Galvanic Excitability.

Ditto		Appearance of First KCC	Appearance of First KD> (Tet.)
Frontal nerve	right	4 cells, 3°	10 cells, 29°
	left	6 „ 14°	10 „ 27°
Spinal accessory	right	4 „ $\frac{1}{2}$°	10 „ 25°
	left	4 „ 1°	10 „ 25°
Ulnar	right	4 „ 1°	10 „ 22°
	left	4 „ 1°	10 „ 20°
Peroneal	right	8 „ 5°	12 „ 27°
	left	4 „ 1°	10 „ 19°
Radial	right	4 „ 4°	10 „ 21°
	left	6 „ 4°	12 „ 21°

So there was here, too, a remarkable increase of galvanic excitability, as is best seen by reference to the normal schema (p. 151).

Investigation with the other excitants showed also a great increase of galvanic excitability, and especially anodic opening tetanus comparatively easily induced in the radials.

Right Radial.

KCC with 4 cells, 1° deflection, 150 resistance
AOC „ 6 „ 3° „
KCT „ 10 „ 21° „
AOT „ 10 „ 28° „
ACC „ 12 „ 31° „
KOC „ 12 „ 30° „

Left Peroneal.

KCC with 6 cells, 1° deflection, 150 resistance
AOC „ 8 „ 17° „
KCT „ 10 „ 23° „
ACC „ 10 „ 26° „
KOC „ 10 „ 24° „

AOT could not be brought on even by using 18 cells, 37° (compare schemata, Lect. V., p. 83). These changes in excitability are easily determined in unilateral disease, where corresponding parts are available for comparison. Otherwise we must fall back upon the data already given as normal. In this way they can be satisfactorily established.

Here are two cases in illustration :—

Tabes Dorsalis, Early Stage	Appearance of First KCC	Appearance of First KD>
Spinal accessory	150 resist., 6° deflection	34° deflection
Ulnar { right	" 12° "	37° "
Ulnar { left	" 10° "	34° "
Peroneal { right . . .	" 4° "	23° "
Peroneal { left	" 4° "	21° "

Spinal Concussion ; Slight Paresis and Anæsthesia	Appearance of First KCC	Appearance of First KD>
Left spinal accessory . .	150 resist., 5° deflection	27° deflection
Ulnar { right	" 4° "	30° "
Ulnar { left	" 5° "	33° "
Peroneal { right . . .	" 1° "	18° "
Peroneal { left	" 2° "	17° "

Thus in both cases there was an increase of excitability limited to the peroneals.

A simple exaltation of electric excitability is of rare occurrence and without much importance in diagnosis. Perhaps it would more often be met with if a precise examination of quantitative excitability were more frequently made. It has been observed to a slight extent in various forms of cerebral paralysis (Brenner), in recent hemiplegias, especially in those which are characterised by phenomena of motor irritation (contractures), less often in connection with different affections of the spinal cord, as, for instance, in the early stages of tabes, and perhaps also in some nerves in recent cases of progressive muscular atrophy. All this, however, needs further confirmation. Finally, it has been found more frequently in different forms of peripheral paralysis, usually soon after their commencement, but also some time later, e.g. in certain cases of rheumatic facial paralysis (Erb, Brenner, Berger) and paralysis from pressure in the radial nerve (Bernhardt). I have seen a recent neuritis display the phenomenon (Fr. Fischer); and it has been produced experimentally (Leegaard).

But the increase of electrical excitability *in certain forms of cramp* is a phenomenon of greater interest and importance, and more determinate in its nature. I was the first to show it in a definite form, as it occurred in a case of tetanus where the phenomenon of AO tet. was well marked. I have further observed it in all recent cases of tetanus which have come under my notice, and it would appear that my researches have been confirmed by others (Chvostek, Onimus, Eisenlohr, E. Remak, N. Weiss, Fr. Schultze), and their result accorded a very great theoretical importance. In my earlier observations the exaltation of excitability seemed to be limited to the nerves of the trunk and extremities, but later observers have demonstrated it also in the facial. Further, in recent cases of chorea minor an exaltation of excitability is said to occur, and to be especially marked in hemichorea (M. Rosenthal, Gowers). I have not yet succeeded in establishing this.

This, perhaps, is the place to call attention to a phenomenon which not unfrequently accompanies the faradic excitation of motor nerves and muscles, both in health and disease, and which may be taken by the inexperienced to indicate a pathological condition. I mean the occurrence of a tonic cramp (true cramp) in the muscles excited by a strong or moderate current. Faradic tetanus passes directly into this form of painful cramp, the muscles becoming as hard as a board and not relaxing for some time after the cessation of the current. I have observed this most commonly in the muscles of the calf and thigh, and the flexors of the forearm. It is so far analogous to the cramp induced in the calf or other muscles by quick and violent movement, and must not be confounded with the *persistence* of faradic contraction as we witness it—for instance, in Thomsen's disease, to be described later on. What the cause of this may be, as we find it in many individuals and in certain diseases—e.g. progressive muscular atrophy—when it is very troublesome in treatment and investigation, I cannot say. It would seem always to depend upon pathological changes in the muscle substance.

2. Diminution (Depression) of Electrical Excitability.

With the *faradic* current this is shown by a decrease in the distance between the coils needed to produce the minimum contraction, or the production of a more feeble contraction, than normally with a stronger current—in other words, by a weaker maximum contraction. This weakness of the contraction may become more and more marked, so that the latter shall need for its production currents of progressively increasing strength. Finally, the strongest currents may fail to produce it, and then faradic excitability is said to be lost. But the term holds only for cutaneous excitability. Direct excitation of the muscles by acupuncture exhibits feeble contractions for a long time afterwards.

As illustrations it is best to take unilateral affections where corresponding parts are available for comparison. Slight differences can then be determined. The following are examples:

1. *Rheumatic paralysis of left facial:*

Frontal branch	r. 156 mm.	l. 143 mm.
Mental branch	r. 150 „	l. 135 „

Tissue resistance being the same for both sides.

2. *Paralysis from pressure of right radial:*

Radial (in the arm) . . .	r. 142 mm.	l. 154 mm.

Deflection in both, 5°.

3. *Progressive muscular atrophy, more marked on one side:*

	Sound Side.	Affected Side.
Ulnar nerve	130 mm.	110 mm.
Median „	155 „	138 „
Peroneal „	140 „	105 „

Tissue resistance alike on either side.

4. *Paresis consequent upon a joint affection:*

Peroneal nerve	r. 178 mm.	l. 105 mm.

5. *Idiopathic muscular hypertrophy of left leg* (*O. Berger, case* 1); *diminution of faradic excitability in the muscles:*

Quadriceps	r. 95 mm.	l. 50 mm.
Vastus externus	r. 100 „	l. 35 „
Gastrocnemius	r. 87 „	l. 15 „
Tibialis ant.	r. 105 „	l. 55 „

Here the resistance to the galvanic current was even less in the left than in the right leg.

But by the use of the method laid down above it is possible even in bilateral affections to determine a sufficiently marked diminution of faradic excitability.

1. *Case of tabes dorsalis in a man aged* 37 :

Frontal nerve . . .	r. 170 mm.	l. 165 mm.	10° resist.
Spinal accessory nerve .	r. 175 „	l. 180 „	8° „
Ulnar nerve . . .	r. 175 „	l. 185 „	2° „
Peroneal nerve . . .	r. 132 „	l. 142 „	1½° „

Hence diminished faradic excitability in the peroneals.

2. *Case of spastic spinal paralysis in a man, aged* 49 :

Frontal nerve . . .	r. 155 mm.	l. 158 mm.	27° deflection
Spinal aceessory nerve .	r. 173 „	l. 178 „	25° „
Ulnar nerve . . .	r. 167 „	l. 161 „	17° „
Peroneal nerve . . .	r. 142 „	l. 148 „	22° „

Here, too, diminished faradic excitability in the peroneals is evident, and it is really greater on account of the diminished resistance in the popliteal space.

Very often faradic excitability can be clearly shown to be diminished in one part only of a nerve, e.g. in the brachial at the elbow, as compared with its branches lower down. So it may happen in progressive muscular atrophy.

Thus :

	At Elbow.	At Wrist.
Median nerve	168 mm.	113 mm.
Ulnar „	165 „	123 „

Here the difference in the distance of the coils to produce the minimum contraction is 55 and 42 millimetres, whereas in the normal condition it does not exceed 10 to 20 millimetres. The same proportion obtains in these cases with the galvanic current.

In another case I derived :

	At Elbow.	At Wrist.
Median nerve	155 mm.	Suspended
Ulnar „	170 „	„

It is obvious that we cannot conclude here without further evidence that the same fibres were excitable at the elbow and no longer so at the wrist. This may have been the fact. But in many instances we might suppose only that the central part of the nerve holds still some excitable fibres while there are no longer such at the wrist. As to which of these is the true explanation in a particular case we may expect to learn by attentive observation of the muscles in the act of contraction.

With reference to the *galvanic current* diminished excitability is manifested by the occurrence of the first KCC with stronger currents (greater deflection of needle). An incomparably stronger current is needed to produce KCT, and so for the other phases of excitation, AC, AD, and KO. Finally the separate reactions gradually disappear. At first no KOC can be obtained. Then the ACC and AOC disappear, soon after KD is lost, and at length the sole remaining reaction KCC can be established only by the use of the strongest currents. If, at last, this in its turn cannot be produced galvanic excitability is said to be lost.

This is the usual mode in which a simple diminution of galvanic excitability is manifested in a nerve. There need not be any qualitative changes affecting the law or the nature of the contraction. This remains throughout short and quick as lightning; it need never become sluggish or prolonged. This is true also for muscles, but only in certain cases. In others qualitative changes occur before this stage is reached. The reactions disappear in a different order, till at last only the ACC remains and the contractions are slow and prolonged. But this belongs to the subject of the reaction of degeneration, which will presently engage our attention.

Here, as before, for the investigation of lesser changes in bilateral disease we must resort to the more accurate methods of quantitative exploration. The more considerable changes are easily appreciable, and with them it concerns us most to determine the absence of coexisting qualitative modifications of galvanic excitability.

I give some examples, beginning, as for the faradic current, with cases of unilateral disease:

1. *Weakness in the peroneal region*, consecutive to a joint affection:

		Sound Side.	Affected Side.
Peroneal nerve	First KCC	25°	35° deflection
	„ KD	40°	absent

2. *Paralysis* (*from pressure*) *of right radial:*

First KCC	r. 22°	l. 10°	deflection
„ KD	r. 34°	l. 31°	„

3. *Atrophy of quadriceps* (*left*), consecutive to inflammation in knee joint (Rumpf):

Crural nerve	KCC	r. 4°	l. 7°
	ACC	r. 5°	l. 12°
	AOC	r. 31°	l. 37°

4. *Weakness and atrophy of right peroneal region* consecutive to inflammation in the knee joint (Rumpf):

Peroneal nerve	KCC	r. 22°	l. 8°
	ACC	r. 32°	l. 23°
	AOC	r. 32°	l. 23°

5. *Encephalitis*, left hemiparesis:

Ulnar nerve	KCC	r. 8 cells,	6°	l. 10 cells,	15°
	KD	r. 14 „	28°	l. 18 „	36°
Peroneal nerve	KCC	r. 4 „	3°	l. 10 „	19°
	KD	r. 10 „	26°	l. 18 „	38°

When the affection is bilateral a close examination yields equally satisfactory results.

1. *Tabes dorsalis:*

Ulnar nerve	right	KCC 8°	KD 32°
	left	„ 7°	„ 32°
Peroneal nerve	right	„ 21°	„ 46°
	left	„ 25°	„ 45°

2. *Tabes dorsalis:*

Ulnar nerve	KCC 6°	KD 30°
Peroneal nerve	„ 20°	„ 40°

3. *Spastic spinal paralysis.* A man, 35:

Frontal, right		KCC 10°	
Spinal accessory nerve, right		„ 4°	KD 35°
Ulnar nerve	right	„ 2°	„ 36°
	left	„ 3°	„ 35°
Peroneal nerve	right	„ 17°	„ 41°
	left	„ 23°	„ 45°

In these three cases the diminution of galvanic excitability is seen to be limited to the peroneals.

The simple diminution of electrical excitability occurs but rarely in cerebral paralysis, and only in a slight degree. It is always in cases of many years' standing, especially in those that had their origin in childhood, and the preservation of excitability is very justly regarded in these cases as a fact of great importance in diagnosis.

Bulbar paralyses, especially of the chronic and progressive kind, exhibit this diminution both in nerves and muscles. In the latter, however, the reaction of degeneration is more common.

In certain affections of the spinal cord simple diminution of excitability is often to be met with, e.g. to a moderate extent in long-standing cases of tabes dorsalis (Erb), in spastic spinal paralysis (Erb), in certain cases of chronic myelitis and multiple sclerosis, in spinal affections secondary to paralysis (Fischer), in unilateral lesions of the affected side (W. Müller, Joffroy, Solmon). A marked diminution, too, often occurs in connection with a simple atrophy of the muscles, which would seem to be something more than the atrophy of inactivity, and which further is unaccompanied by qualitative changes. Perhaps to these should be added cases of acute ascending paralysis (Jaffé, Erb), acute myelitis and other spinal affections (Kahler and Pick), in which a rapid and considerable diminution of electrical excitability has been observed.

In progressive muscular atrophy of that form which I have distinguished as progressive muscular dystrophia—including pseudo-muscular hypertrophy, what I have termed juvenile atrophy, the so called hereditary muscular atrophy and Duchenne's progressive muscular atrophy of children, and which of late has come more and more to be regarded as a primary myopathic condition—there occurs in all the affected muscles a simple diminution of excitability to both currents, which is proportionate to the anatomical change and without accompanying qualitative modifications. On the other hand in progressive muscular atrophy of spinal origin some at least of the engaged muscles exhibit the reaction of degeneration.

In peripheral affections it is important to remember that the central part of the nerves, when paralysis has set in, are no longer within reach of our investigations; that is, these nerves *appear* under all circumstances to have lost excitability because their connection with the muscles is broken, and, in consequence, they cannot exhibit excitability. It is especially characteristic of peripheral paralysis that the nerves at the central side of the lesion are entirely unexcitable by galvanism or faradism, and this fact is often of great use in establishing the exact localisation of the lesion. It results that any modifications which we can observe belong to the distal part of the nerve, and it is only at the beginning of the paralysis, or where the symptom is already disappearing, that ambiguity can arise from the condition of excitability in the central connections.

We must be cautious in assuming the existence of a simply diminished excitability. As a rule it is but a partial manifestation of the reaction of degeneration, presently to be described, and in fact it is only in the nerves that the progressive diminution reaches a total extinction of faradic and galvanic excitability. In the muscles, on the other hand, faradic excitability merely grows less and disappears, while the galvanic goes through quite a series of qualitative and quantitative changes, of which the last expression is the utter loss of that property; still in some peripheral paralysis and certain rare cases the existence of a simple diminution of excitability has been affirmed (Brenner, Bernhardt). Moreover, in the muscular affections to be mentioned presently, there are grounds for assuming a simple diminution of electrical excitability in the motor nerves supplying them.

There is an entire class of muscular affections in which the electrical excitability seems to be simply diminished in a greater or less degree, without any accompanying qualitative change. This is the rule in the rare cases of idiopathic muscular hypertrophy (O. Berger), and in a higher degree in the progressive muscular dystrophia already alluded to, especially in the pseudo-hypertrophic form, in which the diminished excitability presents a striking contrast to the greatly increased bulk of the muscles. But this phenomenon is of greater practical and diagnostic importance in connection with the atrophies and paralysis of muscles which so frequently follow joint affections (in the shoulder, knee, &c.) Rumpf was the first accurately to describe such cases as he saw them in my practice, and I have since confirmed the truth of his statements in many instances. Qualitative changes were invariably absent, and this is of great importance in distinguishing atrophic degenerations.

Seeligmüller has quite recently described some cases of arsenical paralysis in which faradic and galvanic excitability had undergone a marked diminution, without, at the same time, any reaction of degeneration. Da Costa confirms this. On the other hand, a case of arsenic poisoning is reported from Philadelphia, in which the reaction of degeneration was unequivocally present. There are other toxic conditions, too, in which a diminution of electrical excitability appears to obtain. Emminghaus observed it in a case of carbonic acid asphyxia in a very marked degree affecting the phrenic nerves and brachial plexuses; and in those cases, so much written about lately, of alcoholic paralysis, which it is just now the fashion to call *multiple neuritis*, a very great diminution of electrical excitability is constantly described (R. Schulz, &c.) Still I am not convinced but that in these we have to do commonly with only a partial manifestation of the more severe condition, reaction of degeneration. Frequently, too, we meet in practice with old-standing lesions, atrophies, &c., in which examination discloses such a diminution, more or less marked. But in these cases it is difficult, if not impossible, to decide whether we are not in reality upon the bounds of the reaction of degeneration; and in many others a more accurate investigation would, perhaps, disclose the evident marks of that derangement of excitability.

The peculiar case, which E. Remak has lately published, of general neuritis with a greatly diminished electrical excitability even in the unaffected muscles, undoubtedly comes within the province of the reaction of degeneration. A similar case, with a remarkable diminution of excitability likewise exhibited in the muscles which were not involved, was not long ago under observation in my wards, and was published by Dr. Hoffmann. It seemed to me rather to be of central origin, and it certainly yielded a partial reaction of degeneration. Very different from this is the remarkable experience published lately by Westphal. In a boy of twelve years there took place periodical attacks of paralysis of all four extremities, and during these attacks he found the faradic and galvanic excitability of the nerves and muscles throughout notably diminished or entirely lost, without any quantitative change, and again quickly restored after the cessation of paralysis. Unfortunately, the observation was conducted in a somewhat faulty manner. Moreover, a similar diminution of electrical excitability was observed in the case of intermittent paralysis published by Hartwig.

At all events it follows that the diminution of electrical excitability has a certain diagnostic importance, and its less marked degrees, which can only be established by careful examination, seem especially useful in assisting or supporting the obscure diagnosis of many affections (chiefly central and spinal), exposing simulation, &c. As a matter of fact I have succeeded in many medico-legal cases in establishing by means of an accurate quantitative electrical examination what were almost the only proofs of the real existence of disease, and so securing justice for the sufferer.

After death the electrical excitability of the nerves and muscles begins immediately to diminish, and is entirely lost after the lapse of some 2 to 6 hours; so that this loss can be regarded as a certain sign of death, provided that the muscles have not already undergone it in consequence of antecedent disease. And this can hardly happen throughout the entire body.

Next to Rosenthal, Onimus has most closely followed the process, and he has found that faradic excitability after a short exaltation soon begins to diminish, and it is entirely lost after 2 to 2½ hours in the tongue and facial muscles, 3 to 4 hours in the extremities, and much earlier in the extensors than in the flexors, and 5 to 6 hours in the trunk. The length of time which these changes occupy will depend upon the mode of death, the duration of the struggle, &c. The galvanic excitability of the muscles, on the other hand, will be found to persist for some time, even when the faradic is already very low, and the contractions produced by the galvanic current will be sluggish and tonic, lasting longer and confined to the parts in immediate contact with the exciting electrode, until finally they disappear from here too. This, therefore, suggests the phenomena that precede the reaction of degeneration. At any rate the condition, especially as manifested by the faradic current, can be regarded as a certain means of establishing death and ascertaining its nature in a particular case (electrobioscopy).

3. Reaction of Degeneration.

Under this term, which I was the first to use, is included a regular series of quantitative and qualitative modifications of electrical excitability, which are exhibited under definite pathological conditions in the nerves and muscles, being intimately related, as I shall proceed to show you, with certain processes of tissue change (degenerative atrophy) occurring in the nerves and muscles together. This degeneration is characterised essentially by *the diminution and loss of faradic excitability in both nerves and muscles*, whilst *the galvanic excitability of the latter remains unimpaired, is sometimes notably increased, and always undergoes definite qualitative modifications.*

The reaction of degeneration is of the utmost importance in diagnosis. It may be looked upon as the most valuable contribution of medical electricity to nervous pathology, especially since it has been more accurately studied in the long series of experiments by which we have become familiar with its various phases and their pathological import.

A great sensation was created in 1859 by the publication by Baierlacher of a case of facial paralysis in which the facial muscles (and as it was thought at first the branches of the facial nerve too) gave no reaction to the faradic current, but on the other hand responded inordinately to galvanism. From this were conceived the most extravagant hopes, founded upon the superiority of the latter, which it was held was thus established, and shortly was attested in all quarters. Perhaps not even the reintroduction into medicine, by Remak, of the galvanic current was productive of so much good as resulted indirectly from this discovery.

The facts were not unknown before 1859, although they had not been interpreted rightly or accorded their proper value. Already, at the end of the last century, had Hallé followed up the statements of Onimus and Legros, and found in a serious facial paralysis that simple sparks, or even the discharge of a Leyden jar, had no effect upon the muscles of the face, while these responded with forcible and prolonged contractions to the stimulus of a voltaic pile.

Duchenne had observed on different occasions that affected muscles which still retained some voluntary power could not be excited by strong faradic currents, and R. Remak has in various places in his writings pointed out that in many cases more vigorous contractions can be produced by the galvanic than by the faradic current. But it was Baierlacher's discovery that first directed general attention to these facts, and it was followed by independent observations in all quarters (by those of Schulz, of Vienna, Mor. Meyer, v. Grünewaldt, Brenner, Neumann, Ziemssen, Eulenburg, Erdmann, Bärwinkel, Runge, Erb, and others), with the result that the phenomenon was found to occur not only in rheumatic facial paralysis, but in all forms of paralysis, especially those of traumatic origin, and in every nerve. But it was often thought that there was no distinction in this between the nerves and muscles.

Now I established more exactly the fact which had not, indeed, been entirely overlooked by others (Neumann, Bärwinkel, v. Grünewaldt, Runge, Ziemssen, &c.), that the muscles act not to indirect but to direct stimulation, and that the mode of behaviour of the nerves did not differ for the faradic and galvanic currents. The discovery of the reaction of degeneration in traumatic paralysis suggested some experiments which afforded satisfactory results in all the more essential particulars. They established for the first time the various behaviour of nerves and muscles, made known the different phases of diminishing excitability, and especially they showed in the clearest manner the connection between modifications of excitability and the degenerative process going on in the nerves and muscles at once. Experiments undertaken later by v. Ziemssen and Weiss gave precisely the same results with reference to modifications of excitability. The anatomical facts as ascertained have not, unfortunately, yet been published.

After the fundamental facts had been thus determined, numerous subsequent observations, some of an exhaustive scientific character and others of a clinical kind (Brenner, Bernhardt Erb, A. Eulenburg, Rumpf, Kahler, and Pick, Eisenlohr, Kast, Vierordt, and others), threw much light upon the phenomena and true nature of the reaction of degeneration as it is manifested in various conditions. Experiments have been conducted for the same purpose; and the latest—those of Leegaard, which are very complete—give ample confirmation in the main points to the conclusions which I had already arrived at.

Amongst other things we are taught by clinical experience that the reaction of degeneration does not always occur throughout in its full development, but that cases are met with in which it is limited to the muscles, the nerves being more or less unimpaired. It was for this state that I employed the name of *partial* RD. But I wish in the first place to give you a description of the *complete* RD, and then to say something of its partial form and other anomalies.

The fact which is of all others the most important to impress upon you is this: that the process of modification of excitability is different for the nerves and muscles, and that it is, therefore, necessary to consider them separately, and to maintain this distinction alike in investigating the phenomena and in the ideas we form of them.

With reference to the *motor nerve* it happens occasionally that a paralytic lesion is attended with a slight increase of electrical excitability, lasting not more than a day or two; but as a rule immediately, or within a little time (the second or third day), after the appearance of paralysis a progressive, uniform lowering of galvanic and faradic excitability sets in. This is exhibited partly by the retarded appearance of the minimum contraction, partly by the less vigorous contraction which is the greatest that can be obtained by the use of strong currents. Excitability is seen to diminish more and more, so that at the end of the first, or during the second, week it has so completely disappeared that the strongest galvanic or faradic currents, at least when applied superficially, are unable to effect the slightest contraction. The defect begins in that part of the nerve which is nearest to the lesion, and spreads rapidly to the periphery. In this respect the nerve behaves in the same way to both currents. Faradic and galvanic excitability recede in the same ratio at once, and without any qualitative change. This condition of absolute inexcitability varies in its duration. It is very short in milder cases that undergo a rapid cure, lasts a long time—many weeks or months—in more severe and obstinate affections, and is permanently established in those that are incurable.

Then the first signs of returning excitability appear, at the same time for both currents, but not until the repair of the lesion and reproduction of the nerve have made some progress. It is first to be seen in that part of the nerve next the brain, and manifests itself by slow degrees towards the periphery, and it is a long time before it is re-established. These statements hold equally for both kinds of currents and without any qualitative distinction. In mild cases complete restoration is soon effected, but where the injury is more serious there remains an impairment of excitability for a longer or shorter time; and it is not uncommon in these circumstances to find the voluntary power completely re-established, while the electrical excitability of the nerves is undoubtedly defective.

In such cases you will often find the inexcitability of the nerve to remain, when voluntary movements have begun to be performed, i.e. voluntary power is restored while electrical excitability is still suspended, and further this power progresses more rapidly and is finally more completely restored than the latter. Duchenne noticed this in many instances of traumatic paralysis, as far as the faradic current was concerned. And it only means that the nerve at a particular stage is a good conductor of brain impulses but a bad one of electricity. This condition is usually of short duration, but it sometimes lasts for days and weeks, according to the gravity of the lesion, the rapidity of the cure, and the distance of the point excited from the place of injury.

Further consideration of this remarkable fact, which has often been discredited, leads to the conclusion that the conductivity and electric irritability of the nerve are two distinct qualities and may exist apart. Once the connection between the nervous centres and the periphery is re-established at the seat of injury, and a certain amount of repair has taken place, the motor channels are sufficiently open, but they are not yet capable of being excited by electrical currents. For this more extensive reproduction is required. When in the adjoining figure, which represents such a nerve, the part of the lesion lying between *b* and *c* has undergone repair, excitation can be effected by conduction from *a* to the muscle even though the part *c* below cannot be electrically excited. If then the electrical stimulus be applied to the lower part *c* no contraction follows, but if above *b* it will. Now, since the voluntary impulse proceeds from a part higher up, it can also induce muscular action. This fact, which has

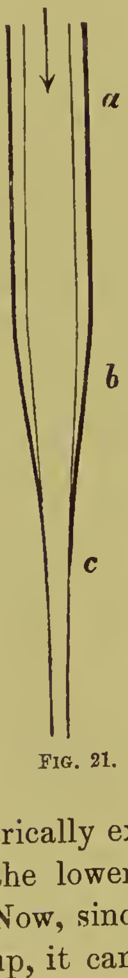


Fig. 21.

been ascertained by experiments, can also be demonstrated in the living body in the case of lesions suitably situated, so that the central nervous connections can be reached by electricity. The difference in efficiency between a voluntary impulse and an electrical stimulus applied to the segment of a peripheral nerve, is therefore due to the difference in the points from which they proceed. At a definite stage of repair the motor fibres can transmit impulses proceeding from above the seat of the lesion, but they are still unable to receive the electrical excitant when applied below that spot. This fact has lately been recognised in physiology after much discussion.

The phenomena of the reaction of degeneration in a muscle are very different from those it exhibits in a nerve; for while the nerve is affected in the same way by the faradic and galvanic currents, the muscle displays much difference in this respect.

To the faradic current indeed the muscle reacts almost exactly as does the motor nerve. Here too a constant decrease of excitability takes place, proceeding, in the course of the second week, to its total disappearance. The strongest currents, at least when applied to the skin, produce then no effect; still if the muscle be exposed or electro-puncture resorted to, feeble contractions can be produced for a long time afterwards, but these are limited to the fibres supplied by the terminal nerves in the immediate neighbourhood of the spot stimulated. This loss of faradic excitability, here, as in the nerves, persists for a longer or shorter time, and, as in their case, it disappears at a certain stage of repair, and slowly returns to the normal condition. The restoration takes place usually somewhat later than in nerves, and also is separated by rather a longer interval from that of voluntary movement. And here again even more than in the nerves faradic excitability remains still for a long time less than normal. The more serious the paralysis and the longer its duration the more protracted will be complete recovery.

It is very different with the *galvanic current.* In the first week, as before, a gradual loss of galvanic excitability takes place. But during the second week, or towards its close, this diminution is replaced by an increase of galvanic excitability, which with the lapse of a few weeks may reach a very high degree of exaltation, and exhibit also certain qualitative changes having reference both to the formula and mode of contraction. This increased excitability is quickly manifested. Very weak currents will suffice to excite the muscles. With 8, 6, 4, and at last even with 2 cells it is often possible to induce opening and closing contractions of considerable energy, while the current is so weak as hardly to affect the galvanometer and to produce no action in the corresponding muscles of the healthy side. Together with this increase of excitability there is a change in the mode of contraction, which becomes constantly more pronounced. Instead of the normal contraction, short and quick as lightning, it becomes slow and prolonged and even with comparatively weak currents passes into a state of tetanus, which lasts as long as the stimulus continues. This sluggish contraction with little energy is especially characteristic of the reaction of degeneration, and is always present, so that it may be regarded as pathognomonic of this condition. The change in the nature of the contraction as well as the increase of galvanic excitability may be well shown where corresponding muscles approach each other at the surface, so as to be reached by the same electrode, as, for instance, at the chin, in facial paralysis of one side. If an electrode be applied here, with each closure of the ascending current contraction occurs only on the paralysed side, the sound one remaining unaffected. If then this is excited, at each closure a short, lightning-like contraction occurs, followed, after some delay, by the sluggish protracted movement of the affected muscles. The same thing occurs in labile excitation of degenerated muscles, where their increased tendency to react and the characteristic sluggish contraction afford a marked contrast to the reaction of the healthy parts, being often visible before this latter is developed by rapid changes (C and O) of the density of the current.

Not less remarkable than this change in the mode of contraction is the qualitative change in the law of contractions displayed at the same time. This depends especially upon the increasing force of the ACC. This soon becomes as powerful as the KCC, and in most cases it is considerably more so (ACC > KCC). Hence besides the sluggish contraction we have another important mark of the reaction of degeneration. And it is incomprehensible to me that the predominance of the ACC has been called in question by some writers (Vulpian). I have demonstrated it so often as a constant and evident fact that I am compelled to regard it as one of the most certain phenomena in human pathology. I will give only a few examples—and in these the numbers cannot show peculiarities which can only be marked directly by the eye :

1. *Chronic anterior poliomyelitis.*

Peroneal region (right) :
First ACC, with 8 cells, 8° deflection } contraction sluggish
,, KCC ,, 10 ,, 19° ,,

2. *Traumatic paralysis of the arm* (advanced stage).

Extensors of forearm :
First ACC, with 12 cells, 24° deflection } contraction sluggish
,, KCC ,, 16 ,, 28° ,,

3. *Paralysis (neuritic) of several muscles of the arm.*

Right biceps :
First ACC, with 8 cells, 14° deflection } contraction sluggish
,, KCC ,, 10 ,, 18° ,,

4. *Progressive multiple neuritis.*

Extensors of forearm :
First ACC, with 10 cells, 7° deflection } contraction sluggish
,, KCC ,, 14 ,, 18° ,,

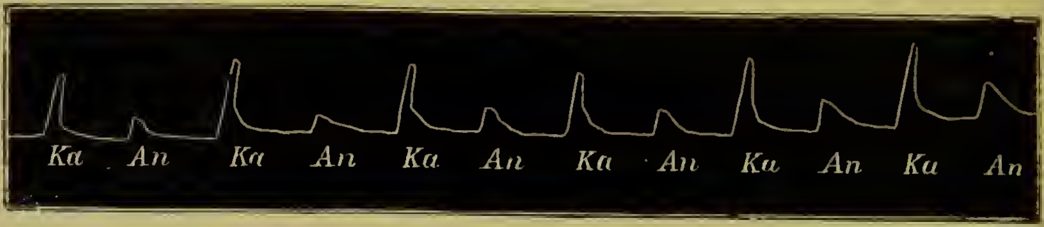
Vastus internus :
First ACC, with 10 cells, 16° deflection } contraction sluggish
,, KCC ,, 12 ,, 21° ,,

Vastus externus :
First ACC, with 12 cells, 20° deflection } contraction sluggish
,, KCC ,, 16 ,, 28° ,,

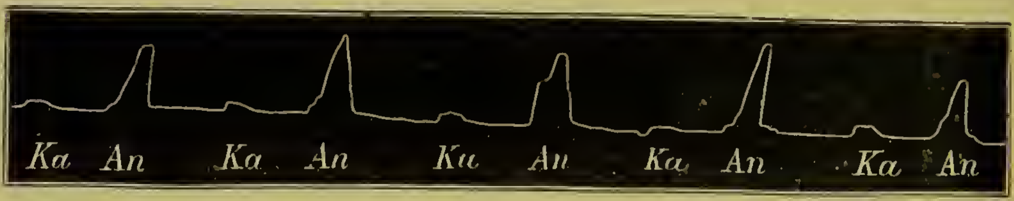
The fact will appear more evident from a consideration of the curves given below, for which I am indebted to my former assistant, Dr. Kast, of Freiburg in Breisgau. The curves taken from the peroneal region show only closure contractions, K = KCC, A = ACC. The first was taken from a healthy individual, the other two from cases which exhibited the reaction of degeneration in the peroneal region consequent upon chronic ant. poliomyelitis. No further demonstration is needed to show the preponderance of the positive over the negative pole than to observe the more gradual ascent and the greater extent of the contraction curves in these as compared with the normal.

What is true of the ACC holds likewise for the KOC. The latter increases more rapidly than the AOC, and very soon becomes equal to it, while the negative opening contraction is rarely greater than the positive (KOC > AOC). I have often observed the fact in a manner that puts it beyond all doubt. It is a point that is not always easy to determine, because the opening contractions, which at first are energetic and easy to observe—much more so than in health—very rapidly disappear from view: partly on account of the tonic closure contractions, which persist until the circuit is opened again; partly, too, because as the contraction becomes slower the muscles lose the power of responding to an excitant of short duration, and the opening stimulus must necessarily be

1. Curve taken from a healthy girl. 33 cells. KCC much more marked than ACC.



2. A case of chronic anterior poliomyelitis, with RD. Curve taken in the peroneal region. 33 cells. ACC notably greater than KCC.



3. The same case. 40 cells in circuit. Ascendency of the ACC and sluggish character of the contractions well marked.

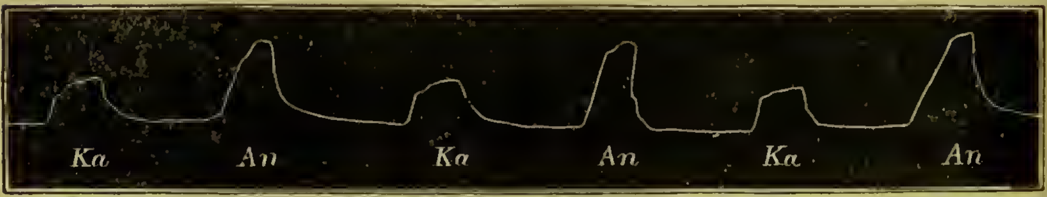


FIG. 22.—Curves exhibiting the closure contractions obtained by direct (unipolar) excitation of the peronei in the leg. K = KCC, A = ACC.

short. Moreover, Leegaard looks upon this absence of opening contraction as exceptional.

This condition of exalted and qualitatively modified excitability persists without further change for a longer or shorter time—3, 6, or 8 weeks.

Then ensues a gradual diminution of galvanic excitability; while the qualitative modifications, especially the sluggish contraction, remain. But in order to produce this sluggish contraction currents of constantly increasing force must be used. In incurable cases this diminution goes on, and it becomes constantly more difficult to excite the muscles. The KCC is first completely lost, and finally only a very feeble ACC remains as the last manifestation of vital energy in the fibres that still survive. It is thus distinguished from the simple loss of galvanic excitability, where the KCC is the last to go. Years may pass before galvanic excitability is entirely lost in the degenerated muscle.

In cases that recover, with the return of voluntary power and excitability the other normal qualities of the muscle are restored gradually, and this takes place more or less rapidly in proportion to the rate in which repair is effected. But you must not expect that the normal condition will be entirely re-established with the conductivity and excitability of the nerves. The changes which have taken place in the muscle require a certain time to disappear, and you must be prepared to find the reaction of degeneration manifested in the muscles for a variable period longer. And so it may happen that normal contractions are produced by exciting the nerves, while at the same time direct stimulation of the muscles shows the qualitative modifications of degeneration. But it is a long time—it may be while excitability is exalted, but more often when it has begun to decline—before the normal reaction begins to be restored; before the ACC grows less, the sluggish contraction becomes less marked and the healthy state is in the way to be completely re-established; and even then, as a rule, the excitability is quantitatively much below the normal, and still a long period will pass before the muscular power regains its former vigour.

As regards the very remarkable difference between the faradic and galvanic excitability of the muscles, which gave the first impulse to more accurate investigations of the reaction of degeneration, it has been attributed by Neumann to physical differences in the currents. He has observed that in similar pathological conditions it is only currents of a certain duration that can excite the altered muscles. And since faradic currents are instantaneous and transitory these have no effect. When by some contrivance the active galvanic current is made of very short duration, it also is rendered ineffective; and this is true though the galvanic current be very strong, and others much weaker, but of a longer action, produce unequivocal results. This explains the fact that it is often possible at a certain stage of paralysis to cause contractions with the use of currents of some duration produced by the rotary magneto-electrical machine, or even with the primary faradic current, while secondary currents have already ceased to have any effect.

This would establish a physical cause for the distinction between galvanic and faradic excitability of muscles; but why it is that degenerated muscles lose the power of responding to currents of short duration, while they react in a more marked manner to those that last longer, has still to be discovered, and it is a question for physiologists to answer. Decidedly there are chemical and molecular changes in these muscles which must be investigated before any light is thrown on the matter.

But there is another phenomenon which appears during the gradual subsidence of the reaction of degeneration, and which certainly is intimately connected with these changes. I mean the *increased mechanical excitability* of the muscles. I was the first to describe it. Hitzig, indeed, discovered it independently, but he has erroneously attributed it to the nerves. It can be seen in all cases more or less plainly, and the muscles are found to respond with an evident but sluggish contraction to any, even a very slight, mechanical stimulus. The best means of eliciting it is a gentle quick blow of a percussion hammer, or the finger, or mere pressure, or sudden extension by weight. The phenomenon is very intimately related to the increased galvanic excitability, but it is exhibited later and lost as a rule earlier than the latter, but under favourable circumstances it can be seen for weeks and months. This ends the description of the chief and typical features (if I may use the words) of the complete reaction of degeneration. If it does not always proceed in the manner indicated, this is to be attributed to the special circumstances of the case, as will be seen more clearly by-and-by. We are concerned in pathology, not with simple and definite symptoms, but with a vast number of phenomena which may further exhibit degrees and modifications without end. This you must keep always before your eyes.

LECTURE X.

Reaction of Degeneration (*continued*)—Its Relation to Degenerative Atrophy of Motor Nerves and Muscles—Description of this—Connection between its Course and that of the Reaction of Degeneration—Complete and Partial Reaction of Degeneration—Occurrence of Reaction of Degeneration—Resulting Inferences as to Diagnosis—Its Prognostic Value—Distinctions and Critical Remarks.

THE ordinary and typical process of the reaction of degeneration has been for the most part explained by experimental investigations, and especially it is beyond doubt that the phenomena of this reaction bear a very close relation to certain histological changes in the nerves and muscles. This we learn alike from experiments upon the lower animals and from observation of analogous spinal or peripheral paralysis in man.

In fact they are the manifestation of a degenerative atrophy in the motor nerves and muscles, of which that which occurs when a nerve is cut or destroyed for the purpose of experiment is a typical example. I have to give you a short account of these changes, so that we may be able to trace the connection between the various stages of their progress and those of the reaction of degeneration. For details I will refer you to textbooks of nervous pathology and the special works that deal with it, of which a great number have been published of late years.

The first consequence of a traumatic lesion of this kind is the degeneration of the peripheral part of the nerve. After a few days (2 to 4) coagulation occurs, the medullary substance arranges itself in a mass of solid particles and drops of myelin, and granulation cells and patches are rapidly formed. This is followed at once by softening, disintegration, and absorption of the axis cylinder, which probably never remains but in cases of slight crushing or under other comparatively favourable conditions (Korybutt-Daszkiewicz). This softening is accompanied by a rapid proliferation of cells in the sheath of Schwann. A large part of the products of disintegration thus formed is slowly reabsorbed, and there remains in the sheath of Schwann only a homogeneous protoplasmic mass, which by some is thought to be produced by the destruction of the axis cylinder, and by others is regarded as a new formation, having some connection with the growth of granular tissue. With its appearance at all events the original histological character of the nerve fibres is lost. The process takes place rapidly; starting from the seat of injury it spreads to the periphery, and reaches the smallest ramifications of the nerve. According to many authorities (Krause, Gessler), it even begins forthwith at the periphery in the preterminal and intramuscular branches. In any case the motorial end plates are destroyed, with an increase of their cellular elements; the branched expansions of the axis-cylinder disappear, while on the other hand the surrounding granular substance, at least in part, remains (Heidenhain, Gessler, Rogowicz).

Compared with these the changes in the neurilemma are inconsiderable. Starting from the traumatic inflammation at the seat of injury there is an increase of the nuclei in the sheath of Schwann throughout, as far as the periphery, and a notable increase in the cellular elements of the endoneurium and perineurium. These cellular elements are changed into fusiform cells and connective tissue, which develops rapidly amongst the separate bundles of nerve fibres and even between the fibres themselves, so as to produce at length the characteristic cirrhosis of the nerve. The question arises as to how this condition of hyperplasia is effected; whether in consequence of the irritation which the products of disintegration set up, or whether it is due to the paralysis of the vasomotor and trophic influences—this is not yet determined.

After some time, longer or shorter according to the nature and severity of the injury, a more or less complete repair of the nerve is effected. And it takes place in all cases where the anatomical conditions are favourable, rapidly in a case of simple bruising, slowly when the nerve is cut or completely lacerated, and more slowly still when the extremities of the nerve are widely separated. We may leave the consideration of these points to histologists, who are already engaged in an endless discussion of intractable problems, and especially that concerning the mode in which connection is restored at the seat of injury itself, and how the old central fibres come again into functional union with the newly formed peripheral structures. For us who are concerned with electrotherapeutics it is of secondary importance to know *how* these things are, so long as we know they *are* so generally. And this is undoubtedly the case under favourable circumstances. Such a re-establishment of conductivity does take place at the seat of injury, and it is certain that the complete regeneration of the peripheral nerves depends upon it alone, notwithstanding that recent observations have shown that a preparatory process goes on in the peripheral parts even before union has taken place. Regeneration of the motorial end plates is even said to be the earliest completed of the constructive changes (Gessler). No doubt the complete re-establishment of the normal structure of the peripheral fibres, under the favourable auspices of the centrifugal trophic influence, is the first to be effected. These fibres, at the outset slender, pale, and non-medullated, become gradually thicker—the growth taking place from the seat of lesion and extending to the periphery—and assume a medullary sheath, which is at first thin, but slowly increases to the normal proportions. But in more serious cases they remain for a long time in an attenuated state embedded in the abundant connective tissue of the nerve trunk, which may be very slowly reconstructed, or perhaps not at all.

Side by side with those alterations in the nerve there occur *histological changes in the muscles* with which they are connected. These invariably undergo a progressive degenerative atrophy. The first evidence of this is the gradual diminution in bulk of the muscular fibres themselves, which, very perceptible by the end of the second week, becomes in a few more strikingly prominent, and in incurable cases may go on to their total destruction. Moreover, the transverse striæ become less marked, but these are maintained, and those cases are exceptional in which fatty or granular degeneration of the fibres has been described. At the same time a considerable increase of the muscular nuclei takes place. They are arranged side by side in little masses and chains, and finally there is a chemical transformation of the muscular substance, which is shown on examination by the increased tendency which such muscles exhibit to undergo the so called *waxy degeneration.*[1]

These changes in the muscular fibres are accompanied by a cellular infiltration and hypertrophy of *the interstitial connective tissue*, similar to that which takes place in the neurilemma ; and here too as a result we have an evident *cirrhosis of the muscular structures*, in which at the end of some weeks the atrophied and attenuated fibres are seen to be surrounded with thick layers of connective tissue. In incurable cases the entire muscle is thus slowly converted into broad bands of connective tissue, which may later become the seat of a fatty deposit.

When the repair of the nerves has taken place, and the action of the central trophic influence upon the muscles is consequently restored, these processes in the muscle cease, and it is gradually restored to the normal state. This, however, takes a long time. The fibres retain their diminished calibre for a considerable period. The hypertrophied connective tissue is an obstacle to their growth, and continues long, and in many instances permanently, to resist the functional restoration and normal nutrition of the muscles.

A large number of experimental and clinical investigations have agreed in showing beyond all doubt that the degenerative processes described above are closely connected with the reaction of degeneration. Their various stages correspond accurately with the degrees in which the latter is developed, and it is beyond question that *the structural changes are the cause of the reaction of degeneration*, alike producing and controlling it. As to how it does so I proceed briefly to explain to you.

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[1] As to whether the distinction which Grützner has drawn, in consequence of his observations upon animals, between two kinds of muscle fibres—the large pale, clear fibre and the smaller dark and granular fibre, with different powers of resistance to the degenerative process, so that the small dark fibres are more persistent—has an important bearing upon the subject of the reaction of degeneration, as this author believes, remains yet to be shown.

The degeneration of the peripheral nerve trunk takes place early, and this is without doubt the cause of the diminution and loss of galvanic and faradic excitability. If the process of degeneration has advanced to a certain point, the electrical excitability entirely disappears, and does not return until the connection between the central and peripheral parts of the nerve is restored, and repair has begun.

So it is that faradic and galvanic excitability of the peripheral nerve trunk is restored with the commencement of repair. But *galvanic* electrical excitability is established somewhat later than the power of conducting voluntary impulses in the nerve or electrical stimuli applied to the central trunk. This depends, doubtless, upon the development of the regenerated fibres. We are free to suppose that these do not become excitable until they have been furnished with a medullary sheath of a certain thickness, at a time when the new fibre has reached a definite stage of development, while at a previous stage it has already become capable of conducting. I will not affirm, for I am not yet sufficiently satisfied of it, that this power of conduction belongs to the naked axis cylinder, while the other property marks the acquisition of a medullary sheath, and that in consequence the axis cylinder in the regenerated fibres must be considered as the *conducting* part, and the medullary sheath as that which receives the electrical stimulus. But this hypothesis seems to me to be very plausible, notwithstanding the objection of Kühne and Steiner that the electromotor action of medullated nerves resides in the axis cylinder, and has nothing to do with the medullary substance. As the new fibres develop their excitability increases in the same ratio. But as a rule it remains for a long time less than normal, partly from a deficient development of the fibres, and cirrhosis in the nerve itself; and still more in consequence of the atrophy and cirrhosis of the muscles, which for a long time yet cannot respond with their usual energy to stimuli conveyed to them by the nerves.

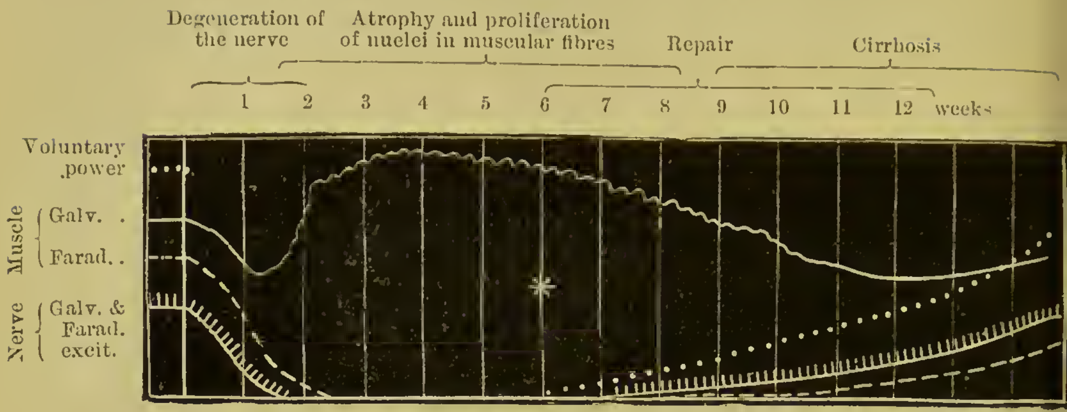
The degeneration of the intramuscular nerves and end organs is probably the cause of the decline of faradic and galvanic excitability which is seen in the muscles during the first week, when the muscular fibres themselves have undergone no change. To the histo-chemical changes which then ensue in the striated substance are undoubtedly to be ascribed on the one hand the inexcitability to faradic currents of short duration, and on the other the very great increase and qualitative modification of galvanic excitability. As to how this happens, and what is its proper explanation, we have as yet no knowledge. Decidedly it appears to me premature to assume, as Gessler does, that the atrophy of the fibres is the cause of the slowness of the contraction, and the cellular proliferation that of the increased excitability. The matter is certainly not so simple as this. Moreover it remains yet to determine with any certainty the part which the persistent granular bodies of the motor end plates with their altered conditions of excitability (Heidenhain, Rogowicz) play in the quantitative and qualitative manifestations of the muscle. These degenerative changes once begun, the progressive atrophy of the muscular fibres leads in due course to the diminution of galvanic excitability. The cessation of the process in consequence of repair, and the growing bulk of the muscle, determine the restoration of normal excitability in both its quantitative and qualitative aspects, as also of faradic excitability when repair has made certain progress in the nervous and muscular fibres. Even after voluntary power is completely recovered, a simple diminution of electrical excitability of the muscles will remain for a long time. This is readily explained by the hypertrophy of the connective tissue and the obstacle which this presents to the formation of new fibres. At all events this mass of connective tissue is an intrinsic source of considerable resistance to contraction in the muscle itself.

The truth of the statements which I have made upon this subject is proved by the united testimony of all the experiments and clinical observations which bear upon it. They serve also to impress upon us the importance of the inferences which can be drawn from the presence of the reaction of degeneration, in its various phases, to the coexistence of corresponding stages of degenerative atrophy in the nerves and muscles that display it; and it would be hard to derive from physical modes of investigation in any branch of pathology equally certain information concerning the minutest histological processes. That you may understand me the better, and to impress these facts more deeply on your memory, I subjoin three schemata to represent the reaction of degeneration and its relations with degenerative atrophy. You can draw from them several conclusions. In all three the first ordinate marked by a heavy line indicates the occurrence of the injury; the sudden cessation of motor power is shown thus (°°°°°), and its commencing restoration by an asterisk (*). In the first schema you have a speedy return of motor power, in the second it is more delayed, and in the third none at all takes place. They represent, then, respectively, a mild, a more serious, and an altogether incurable case. The numbers placed above the different ordinates mark the number of weeks that have elapsed since the injury took place. The undulatory tracing which represents the galvanic excitability is intended also to show its qualitative modifications. The short notes placed over each schema point out approximately the stages of the histological process going on in the nerve and muscle. Of course these diagrammatic representations cannot pretend to great accuracy on account of their small size; but they exhibit at a glance the course and connection of phenomena in the three chief classes of cases, between which, it is needless to say, all imaginable transitions may occur.

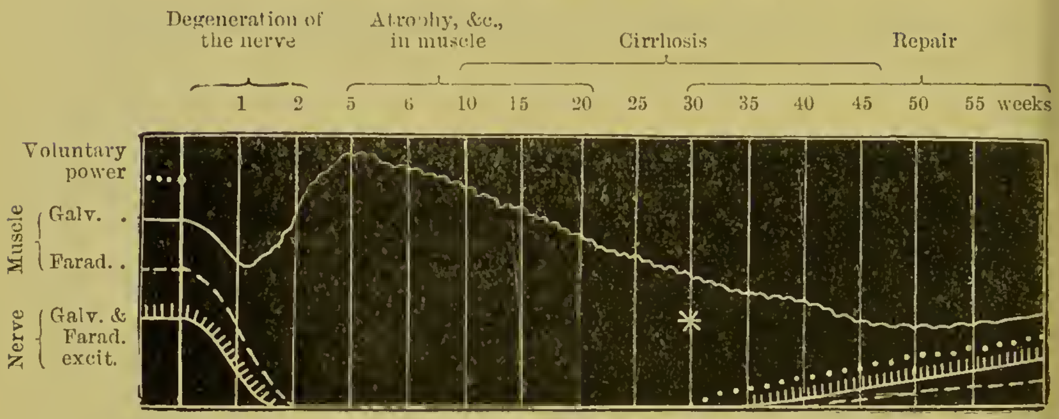
You see in the three tables, in the first week, the diminution of excitability in the nerve and muscle, marked by degeneration of the nerve; in the second week the extinction of excitability in the nerve and of faradic excitability in the muscle—at the same time commencing increase and qualitative modification of galvanic excitability in the muscle, marked by atrophy and cellular hyperplasia in the muscular fibres; in the sixth week in table (1) the return of motor powér; in the seventh and eighth weeks the return of galvanic and faradic excitability in the nerve, and of faradic excitability in the muscle, marked histologically by the commencement of repair.

In table (2) you see that in the twenty-fifth week there is already a notable diminution of galvanic excitability with persistent qualitative modification corresponding to the atrophy and cirrhosis of the muscles, &c. In this way you can read in each series, for the different forms of paralysis and their various

Paralysis with comparatively speedy restoration of voluntary power.



2. *Paralysis with more tardy restoration of voluntary power.*



3. *Incurable paralysis. Voluntary power unrestored.*

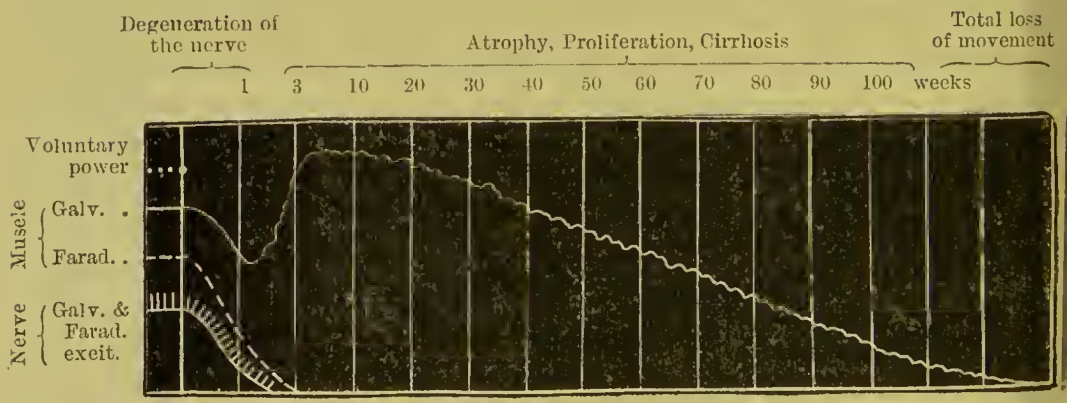


FIG. 23.—Diagrammatic representation of the complete form of the reaction of degeneration, with reference to the degree of voluntary power and the faradic and galvanic excitability of nerve and muscle, exhibiting also the concomitant histological changes.

stages, the way in which the motor power and electrical excitability appear at a definite period, and the histological associations of each. You see at once that the character of the electrical and histological modifications which constitute the reaction of degeneration may vary at any time, within the widest limits, according to the greater or less rapidity of the process of repair.

Such would be the representation of the *complete* reaction of degeneration as we often see it, but with such regularity only in typical cases. Of course, gentlemen, you must not expect to find in every pathological condition so great a uniformity in the course of these modifications as is to be met with in experiment or in a simple traumatic lesion of the nerves. This does not often occur in disease where many deviations may be caused by the nature of the injury, different affections of trophic influences, occasional improvement, or new elements of disturbance following one upon another; and one is not warranted in concluding from some irregularity, such as always presents itself in long-standing cases, that these schemata are incorrect, or that one has discovered some fresh anomaly. The time at which repair takes place determines great differences in the general manifestation of the reaction of degeneration. If this happens early the nerve may be endowed with galvanic and faradic excitability while the changes in the muscle are at their height. These latter cannot be reformed so quickly, and require for the purpose some lapse of time. It may happen, then, that when the nerve is excited the muscle responds with normal contractions, but still when stimulated directly exhibits the reaction of degeneration. But if repair sets in very late it may be that the muscular galvanic excitability is already greatly diminished when the electric excitability of the nerve begins to be slowly restored. There is, therefore, an indefinite number of special cases, which nevertheless may be mastered by carefully attending to the conditions of time and other circumstances. To this end the schemata given above may be usefully applied.

But there exists a class of cases in which the process does not correspond at all to the schema. In these it is only some of the modifications that are typically developed. The others either do not occur or do so very slightly. In these instances the excitability in the nerves is not entirely lost, but becomes diminished to an almost inappreciable extent. In spite of this we find the galvanic modifications typically displayed in the muscles. I found this phenomenon first in a series of six facial paralyses of a rheumatic character; and I have made use of them to establish a special class of these paralyses, and to define a kind of secondary reaction of degeneration.

Bernhardt has since observed such a case. Since then, too, I have myself frequently seen the phenomenon in certain forms of atrophic spinal paralysis and in peripheral paralysis of various nerves. I have, in consequence, introduced the term *partial reaction of degeneration.* It is very easily defined, and the manner in which it is exhibited may be readily seen by reference to the following schema.

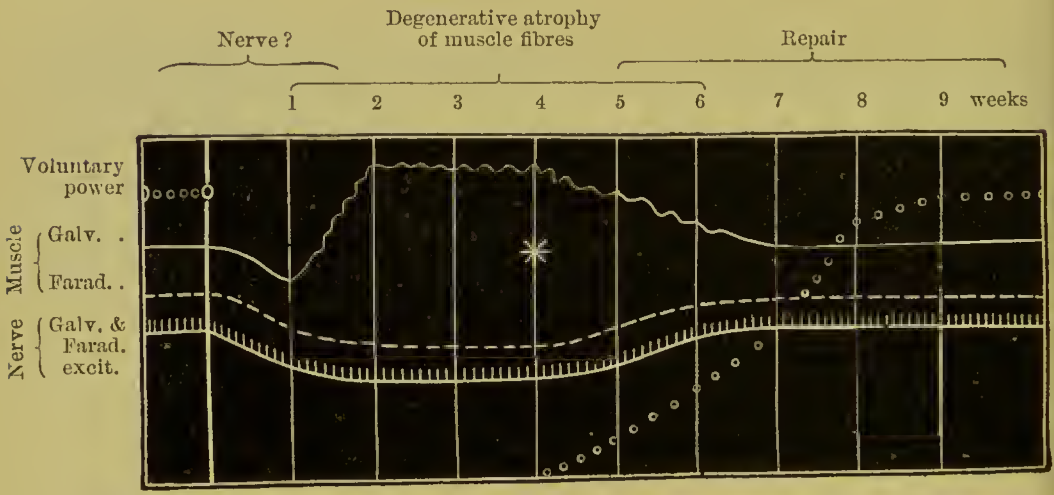


FIG. 24.—Graphic representation of the partial form of RD. The faradic and galvanic excitability of the nerve, and the faradic excitability of the muscle, are but slightly lowered. Voluntary power soon restored. Recovery rapid and complete. There was probably no degeneration of the nerve.

There takes place, in the nerve, only a very slight diminution of galvanic and faradic excitability, which in different cases proceeds to a greater or less extent, and is often insignificant but always quite appreciable. It is exhibited frequently rather by a lesser maximum contraction than by the later occurrences of the minimum. In the muscle also there is a corresponding diminution of faradic excitability, while galvanic excitability displays the same quantitative and qualitative changes as are met with in the complete reaction of degeneration, the same remarkable increase of excitability, the same slowness in contraction, the same ascendency of the ACC over the KCC. There is, then, in galvanic exploration, a complete conformity with the reaction of degeneration. But we know from experience that in all such cases where the symptoms belong to this form of *partial* reaction of degeneration, the disorder is comparatively slight and tends to a proportionately rapid cure.

It is natural and perhaps reasonable to conclude that the nerve in these cases undergoes no degeneration, or does so only to an inconsiderable degree, and that it has merely suffered some slight molecular or nutritive impairment; while the muscles display fully the same changes, which, moreover, as they affect the fibres, are histologically of the same nature as those to which we have attributed the modifications of electrical excitability above. Unfortunately there are no very accurate anatomical investigations bearing upon the matter, and although Ziemssen and Weiss have succeeded in experimentally producing paralysis with the partial reaction of degeneration, and Stintzing in his researches upon nerve-stretching has also observed it, the accompanying tissue changes in nerves are not sufficiently understood.

Still you must not suppose that this *partial* RD is something specific and altogether different from the complete form. On the contrary they are very closely related, and a larger experience, such as I possess, in these matters goes to show that all possible transitions occur between the normal reaction and the partial RD and again between the latter and the complete reaction of degeneration, so that it would be possible to determine a regular series of instances of variously deranged excitability from the least considerable to the most severe.

You may often see the partial and complete reaction of degeneration occurring side by side, in different regions, but in the same affection and the same individual; and I have repeatedly observed the condition which at the outset was partial become gradually, in the very same nervous and muscular structures, the complete reaction of degeneration.

Of course this partial RD is not to be confounded with those cases in which with the process of repair the excitability of the nerve is restored, while at the same time the muscles exhibit the reaction of degeneration. But the discrimination will present great difficulties where accurate information cannot be had as to the course and development of events.

Circumstances under which the Condition occurs.

Having given you a full account of what is known of the nature of the reaction of degeneration, it remains for me now to enumerate briefly the disorders in which it occurs.

You will have already foreseen that it must certainly be present in all pathological conditions which are analogous to the experimental cutting or bruising of motor nerves—that is to say, in all so called traumatic paralyses due to injury, section, laceration, or extensive bruising of the nerves. Of these the illustrations are innumerable. That large class of paralyses attributed to compression or pressure must be included here, since in them the nerve is so far impaired as to interfere with the trophic influences. You will be told by-and-by that this is not always so, but that there are paralyses due to pressure, of a less serious nature, in which the power of conduction alone suffers, while the unaltered electrical excitability would lead to the belief that trophic disturbance of any consequence was also absent. I include among these paralyses due to pressure, not only those whose causes are mechanical and external (sleeping on the arm, tight bandaging, tourniquets, tedious labours, heavy fetters, ill-made crutches, &c.), but also those which are due to pathological processes within the body (tumours, aneurisms, hæmorrhage, cicatricial contraction, plastic growths, joint luxations, &c.), which involve the motor nerves. To this class belong the so called *neurotic* paralyses, especially those in which there is interstitial neuritis in the first instance with resulting mechanical pressure upon the motor fibres, whereas in those cases which have lately been described as parenchymatous neuritis the condition is a primary degeneration of the nerve fibres with impairment of conductivity in their course. But this impaired conductivity may also arise in course of an interstitial neuritis. Even here the reaction of degeneration will obtain if the destruction of conductivity is complete, involving also the trophic supply. The reaction of degeneration is also manifested in many rheumatic paralyses, especially in certain facial forms, which, indeed, were the starting point of an accurate knowledge of its nature. Since we do not yet know the anatomical basis of these rheumatic lesions, we cannot say how the reaction of degeneration is produced. But it is very probable that here, too, slight changes in the nerve, leading to compression, is the cause, the more so as these nerves are buried in very narrow bony canals. Further, the reaction of degeneration is met with in spinal affections, especially those in which the anterior grey columns of the cord are implicated or diseased; notably, therefore, and habitually in the different forms of anterior poliomyelitis; in its most acute manifestation, infantile spinal paralysis; in its subacute and chronic forms (Brenner, Salomon, Erb, Seeligmüller, &c.); in the disseminated chronic, progressive variety (the typical progressive muscular atrophy—Erb, E. Remak, Vierordt, Günther); in the analogous bulbar disease, chronic progressive bulbar paralysis (Erb, de Watteville, Eisenlohr); and therefore, as might be expected, in the so called amyotrophic lateral sclerosis (Eisenlohr, Pick, E. Remak). In this last I have myself been often able to demonstrate it in several characteristic cases. In all these chronic affections which I have just enumerated the reaction of degeneration is usually exhibited in some only of the muscles, and often only in its partial form. This last, moreover, can be observed in all known forms of disease—*serious* traumatic paralyses, of course, excepted—and it is often well marked and extensive.

You will not be surprised to learn that the reaction of degeneration is present incidentally also in hæmorrhages in the spinal cord, or hæmatomyelitis (Erb, E. Remak), when the anterior grey columns of the cervical or lumbar enlargement are engaged; and, under the same conditions, in acute and chronic myelitis and tumours of the cord (Erb and Schultze). So likewise it may be said to be a constant phenomenon in lead poisoning (A. Eulenburg, Bernhardt, E. Remak, Erb), as to which we are yet ignorant whether the lesion is in the anterior grey columns or in the course of the motor fibres. I may mention here that I and others (Bernhardt, de Watteville) have often found the reaction of degeneration in cases of lead paralysis, exhibited in muscles which were not yet paralysed, and in which, consequently, the changes were clearly of a trophic nature.

You will readily conceive, too, that the reaction of degeneration is likely to present itself in *diphtheritic paralyses* because you know that these are now, at any rate to a great extent, and rightly, attributed to degenerative processes in the nerve trunks and their motor roots. Obviously, too, it will arise in connection with *paralyses consecutive to acute affections*—neuritis, hæmorrhages, poliomyelitis, &c.—as well as in *syphilitic paralyses*, &c. Notwithstanding all this, which has been established by long experience, it must be affirmed that the reaction of degeneration has never been met with in paralyses that have their origin in the brain itself, proceeding from a lesion in the motor channels above the grey matter of the medulla oblongata, or in the cerebral cortex; and that it never occurs in paralyses due to injury of the white columns of the cord, unless, of course, in the anterior roots. Neither does it occur at any time in hysterical paralysis.

But I would lay stress especially upon this point, that the reaction of degeneration is never met with in primary muscular affections of undoubtedly local origin; it does not arise in myositis, still less in the atrophies and pareses of muscles so often consecutive to joint affections (Rumpf). I have at this moment notes of a large number of cases, none of which presented any indication of it. It is also absent in *consumptive* atrophies and atrophies of inactivity, even the most extensive.

Before we apply our knowledge of the reaction of degeneration to the purposes of diagnosis and prognosis we shall consider shortly, and as objectively as possible, what conclusions—positive or negative—can be drawn with certainty from its presence. Now in my opinion the only certain and unquestionable inference which it affords is this: Wherever the reaction of degeneration occurs there exist considerable anatomical changes, i.e. *degenerative atrophy in the nerves and muscles, eventually in the muscles only*; and we can infer with great certainty from the actual condition of the reaction of degeneration the extent, intensity, and degree of these degenerative changes.

Having regard to the views which are now almost universally held upon the conditions of degenerative atrophy in the motor apparatus, and its dependence upon nervous derangements, another conclusion of great importance results: *When the reaction of degeneration is present it always points to a nervous origin of the disorder* (paralysis or atrophy) and to the existence of a serious disturbing agency somewhere, *either in the peripheral motor channels*, or in *the trophic centres of the brain or cord*, and in particular, therefore, the anterior grey substance of the spinal cord and medulla oblongata.

To explain these statements it will be well to devote a few words to the most plausible theory in the light of recent observations concerning the trophic relations of the motor structures. Much energy and acuteness has been employed in the study of these relations, and fairly satisfactory conclusions have been arrived at, thanks to modern advances in the pathology of the cord, although many are still in the condition of hypothesis. Briefly, this is what is at present received:

The motor nerves and muscles, so far as their nutrition is concerned, are under the control of certain central nervous agencies, which may be called for short 'trophic centres.' The constant action of these centres maintains the nerves and muscles in their normal structural (and functional) condition. (The trophic influence reaching the nerves from the periphery or the muscles [W. Kühne, Rumpf] has no bearing upon this matter.) From all that we know it results that we have to look for these trophic centres of the motor apparatus in certain parts of the grey substance of the cerebro-spinal axis, especially in the anterior grey columns of the spinal cord and the nuclei of grey matter analogous to them in the floor of the fourth ventricle. We may suppose, according to all appearance, that the large multipolar ganglion cells, or at any rate some of them, exercise these *trophic* functions.

A breach in the connection between this central apparatus and the peripheral nerves and muscles entails derangement of their trophic supply, and the distal parts in consequence undergo a progressive degeneration (in point of fact our degenerative atrophy), and continue to do so until the connection with the centres is re-established. It matters little in the end whether the breach is effected by an arrest in the conducting power or by a solution of continuity in the *peripheral nerves*, or proceeds from destruction and functional disintegration of the *centres*. In either case, degenerative atrophy is the inevitable result.

Such is, at all events, the simple interpretation of facts. As to the precise way in which these trophic influences are exercised, whether they are conducted to the nerves and muscles by distinct trophic fibres or conveyed by the motor channels, whether there are separate centres and fibres for the nerves and for the muscles—all these are matters of conjecture. But conjecture obtains much support from a number of facts of which we now possess information, and especially from the phenomena of the partial reaction of degeneration. All that I have seen of the latter, and in particular the extensive clinical experience that I have had of the controlling functions, renders it impossible for me to concur with Wernicke that the partial reaction of degeneration depends only upon an incomplete atrophy of the nerve fibres. On the contrary, I am firmly convinced, by a consideration of all the facts bearing upon the matter, that there are separate centres and channels for the trophic supply of nerves and muscles; or at least if we are to assume but one centre for both, as Rumpf does, that the trophic impulses to the muscles have to encounter greater resistances in their course; and so, other things being the same, become paralysed sooner than those to the nerves. In other words, in the event of a functional impairment of the trophic centres, or the occurrence of comparatively slight obstacles in the course of their conducting channels, the most distant parts—that is, the muscles—in the first instance alone undergo degeneration, but the motor nerves themselves are subsequently attacked, and the process may gradually extend to the centres. Many instances might be cited in support of these views (e.g. progressive muscular atrophy, chronic anterior poliomyelitis) in which the distal parts of the nerves are already inexcitable, while those more central continue to respond to excitation. Perhaps in this way, too, are to be explained some of the facts of 'ascending neuritis' and many of the phenomena of lead paralysis and the so called parenchymatous neuritis.

At all events the facts hitherto observed agree in showing that degenerative atrophy in the strict sense, and with it the reaction of degeneration, is confined to nervous affections, and to those only that have a well-defined seat. And it certainly does not occur in primary muscular affections. I am in possession of a large number of records bearing upon this point, and hitherto I have not met with any conflicting testimony.

On the other hand there are cases of simple atrophy of the muscles, it may be of a very extensive kind, unaccompanied with degenerative changes and not marked with the reaction of degeneration. They occur often enough in the later stages of serious spinal paraplegias, and also at times in the course of severe cerebral paralysis. A somewhat analogous condition is progressive hemilateral atrophy of the face. In accordance with our present experience we might suppose that in such cases the anterior grey columns remain unimplicated. This theory obtains valuable confirmation from a case of spinal disease lately published by Strümpell. In this there was extensive atrophy without degenerative change in the muscles, and without the reaction of degeneration, and the anterior grey columns were found intact. In spite of this we are yet ignorant of the true cause of this form of atrophy. Whether it must be regarded as one of simple inactivity, or as another variety or degree of trophic disorder, remains yet to be decided. Perhaps, too, we should include in this class some of the muscular atrophies that are so commonly consecutive to joint affections.

To return from this digression to the reaction of degeneration: Its presence as a means of diagnosis conveys but one positive inference, and that is the existence of certain histological changes—namely, degenerative atrophy in the nerves and muscles—and from this results directly a judgment as to the gravity of the lesion and the extent to which the power of conduction is involved. As to the seat of the injury, all that we learn from the reaction of degeneration is that we have to deal with a nervous disorder, and that its seat must be either in the peripheral nerves, the motor roots, or the central grey substance. Its presence enables us absolutely to exclude cerebral disease in the strict sense. But it does *not* enable us, as was long believed, to affirm the existence of a peripheral lesion. This would be a cardinal mistake. It is as likely to be spinal, and in order to determine its situation we must resort to a consideration of other crucial symptoms and a more extended investigation.

The presence of the reaction of degeneration can hardly be said to aid in forming an opinion of the nature of the lesion which was the cause of the paralysis, since it occurs in the most various forms of disturbance. On the other hand, in many cases it is of very great practical use in prognosis. The principle may be stated thus :

Other things—that is, the cause and nature of the disease—being the same, the lesion is serious, the probable duration of the disease longer, the definite prospect of a cure more remote, in proportion as the reaction of degeneration is developed and complete, and to the stage which it has reached. The partial is, therefore, a more favourable condition than the complete reaction, and its later less so than its earlier stages. It is possible, therefore, in the different forms of disease to arrive at a prognosis, which of course should be supported by independent considerations. In this respect the most instructive illustration may be drawn from rheumatic facial paralysis. Of this, three forms are distinguished, according to the duration and severity of the disease, and each may be recognised by means of electrical exploration. If electrical excitability is found to be altogether normal (mild form) prognosis is very favourable ; the disease will last two or three weeks. If there is a partial RD (intermediate form) it will last one or two months ; but if the reaction of degeneration is complete (serious form), the prognosis is proportionately bad and the paralysis will last 3, 6, or 9 months, and even longer. The numerous cases of paralysis by compression of the radial nerve can also be estimated as to prognosis by means of electrical exploration. So too in a variety of spinal disease—chronic anterior poliomyelitis—inferences have been drawn from the condition and degree of the reaction of degeneration, both with reference to different muscles in the same individual and to the milder and more severe forms of the affection (Erb), and these have been vindicated by the result.

But in this connection it must not be forgotten that the reaction of degeneration is not available for prognosis in every kind of paralysis without distinction. The comparison must be instituted only between those in which the cause is known and its localisation the same. It is, therefore, applicable only to facial paralysis of rheumatic origin as a class, and so, too, to cases of paralysis by compression of the radial among themselves. It is never admissible, for instance, to apply the criterion of electricity in the same way to a cerebral facial paralysis and one proceeding from caries of the petrous portion of the temporal bone, or to the latter and a rheumatic paralysis, or again to paralysis of the radial, due to compression and radial paralysis, consecutive to the formation of callus, or progressive muscular atrophy in the radial region. This, I repeat, is inadmissible.

The account which I have given of the reaction of degeneration does not pretend to have exhausted the subject in all its aspects and details. My object was only to give an idea of it in its typical form, and to show you how it habitually occurs in simple and uncomplicated cases. I now proceed to add some remarks of an explanatory and distinctive kind.

It is of the nature of this condition to exhibit every kind of departure from its typical manifestation. Pathology is concerned not with a simple and readily interpreted expression of facts, but with morbid states of varied form, manifold, complicated and ever-changing. The more or less tardy development, improvements, occasional relapses, the symptoms of degeneration and repair, all these are blended in confusion and will not lend themselves to any principle of uniformity. Circumscribed or variously disseminated lesions, affecting with their several combinations only certain parts of the nerves and muscles ; renewed invasions of degenerative atrophy in the same nervous and muscular regions, as in the case of recurring lead paralysis ; the coexistence of several disturbing agencies which may lead at the same time to different derangements of the electrical excitability—these are some of the confounding elements which may interfere with the usual process of the reaction of degeneration. The natural result is an infinite variety and complication of its phenomena. These we must be prepared to meet with, and we can hope to disentangle and explain them only by keeping always before our eyes the contingencies which I have mentioned.

Above all things it is imperative that the investigation be performed with care and the utmost address. Long experience is needed to ensure a familiarity with the reaction of degeneration, under the most unfavourable circumstances, and a recognition of its characteristics in cases where they are least readily appreciable.

It is especially useful in the later stages to introduce into the muscles currents that are quantitatively as great as possible, so as to compensate to some extent for the already diminished excitability. You must, therefore, employ large electrodes, thoroughly moisten the skin, increase the strength of the current by reversals, placing both electrodes in the last resort upon the muscle, and endeavour as far as possible to eliminate the misleading effects of contraction in other muscles. This last is a point of special importance in the examination of the small muscles of the hand, as those of the thenar eminence and the interossei, and it is easily effected by placing the indifferent electrode at the wrist either on its dorsal or palmar surface.

By conducting the examination in this way, in conformity with the laws of Ohm, you will succeed in most instances in distinguishing the comparatively feeble and sluggish contractions of the reaction of degeneration from the stronger and more energetic ones of the neighbouring muscles. This object may be facilitated by placing the part in such a position as to prevent the movements of the healthy muscles.

If in the later stages the muscles are inert, and excitability very much diminished, it may happen that repeated efforts are needed to evince it. It is of great use in determining a commencing reaction of degeneration, or one that has not made much progress, to bring about a kind of 'double contraction,' such as I have often noticed and made apparent in these cases. It consists of a rapid, lightning-like contraction of the healthy muscles in the vicinity, which takes place at the moment of closure, to be followed directly by the slow and characteristic movement of the reaction of degeneration. It is easily shown in lead palsy, where in exciting the extensors at the forearm, a short lightning-like flexion of the hand and fingers precedes their slow and somewhat protracted extension. It is very instructive to witness, at the outset of the reaction of degeneration, the occurrence, in one and the same muscle, of a rapid and vigorous contraction with the KCC, and directly afterwards the slow and protracted response to the ACC. This can be seen, especially well marked, in the large and bulky muscles, as the biceps and triceps of the upper limb and the vastus internus.

In many instances of the reaction of degeneration the period of increased excitability is seen to be very short, or it may be entirely absent, and then the qualitative changes are the only indications. In general I attach more importance to the character of the excitability—certainly when it is protracted—than to its increase. The reaction of degeneration may in all cases be most surely recognised by the slow, prolonged, and impersistent contraction, and by the ascendency of the ACC. In long-standing cases, of slow progress, it is often impossible to determine anything definitely. In these we frequently find nothing but a simple diminution of excitability even to the galvanic current, and, unless the ACC is the only reaction left, there may be a doubt as to whether the reaction of degeneration has existed at all. The simple diminution of electrical excitability may be complicated by spinal disturbances, and in many cases apparently it may proceed to great lengths. These cases demand painstaking researches, with much expense of time, and as a rule they are not published, since they lead to no remarkable discovery. I may mention here an interesting case of which the particulars have been recorded by Kahler and Pick. Unfortunately the nature of the affection was not clearly made out. Possibly it was spinal disease or a multiple neuritis, it may be both together. While the reaction of degeneration was fully developed in several groups there was in separate muscles only a quantitative diminution of excitability. In others ACC > KCC with contraction of normal vigour, and not sluggish. And, further, in parts of the nerves and muscles which had never been paralysed there was a notable diminution of faradic excitability. Bernhardt has observed precisely the same phenomena in a case which he regarded as subacute anterior poliomyelitis—namely, great diminution of faradic and galvanic excitability in a large number of motor nerves and muscles, which still showed no evidence of paralysis. The condition here, I have no doubt, was a process of degeneration and repair differing in its rate of progress and extent in the nerve and muscle, and so producing the most various manifestations in the several parts involved. Perhaps, too, complications had their share in this.

It is a remarkable fact, and one of great theoretical importance, that *a well-marked reaction of degeneration is occasionally seen in muscles which show no signs of paralysis*, or whose motor power is only inappreciably impaired. I was the first to demonstrate this in a case of lead palsy. The deltoid showed no loss of motor power, but marked and typical changes of galvanic, with slight decrease of faradic, excitability. Unfortunately, the nerve trunk was not examined. There was here, therefore, an isolated trophic derangement in the muscle, without any appearance of an obstacle to the conducting power for motor impulses. Bernhardt afterwards observed the same phenomena in lead paralysis obtaining in an entire group of muscles (deltoid, biceps, and brachialis internus) which were functionally perfect and not paralysed. These muscles exhibited a well-marked reaction of degeneration, whilst the galvanic and faradic excitability of the nerve were lowered. Kast has recently described a case of mine where there was a complete reaction of degeneration at the thenar eminence in muscles which were functionally intact—that is to say, the nerve could not be excited by galvanic or faradic currents. Bernhardt also has lately noticed this in four cases of traumatic paralysis of the median, coming under his observation for the first time in 4 to 8 weeks after the injury. They showed a complete reaction of degeneration, with perfect or nearly perfect motor power, but marked anæsthesia. Buzzard too in a case of lead poisoning has seen faradic excitability at all events diminished in unparalysed muscles, and Kahler and Pick have found the reaction of degeneration in muscles which, though much enfeebled, were not paralysed. These cases constitute the insensible transition to the *partial* reaction of degeneration as I have often seen it in progressive muscular atrophy and a certain *intermediate* form of chronic anterior poliomyelitis. In these last, however, there is always an impairment of muscular power, even though it does not amount to actual paralysis. With these may be mentioned the two cases quoted above of E. Remak and Hoffmann (from my practice), but they are peculiar in that there was a very great diminution of excitability at the same time that the qualitative changes in the muscle which are characteristic of the reaction of degeneration had more or less disappeared. Such cases, however, are still very obscure.

A condition in which the nerve reacts differently to the faradic and galvanic currents in a manner analogous to that of muscles in the reaction of degeneration has hitherto been observed only in rare instances (Erb, Cyon, Bernhardt, Leegaard), and is altogether exceptional. I shall return to this subject later on.

But a more noteworthy fact is that at a particular period in certain forms of the reaction of degeneration the degenerated muscles respond with an extremely sluggish contraction both to faradic excitation and to a stimulus applied to the nerve. I was the first to describe this in a case of traumatic ulnar paralysis (in 1868), where with faradic excitation of the nerve over the wrist-joint I got a feeble, slow, and prolonged contraction. Direct excitation of the muscles with strong currents also gave protracted and sluggish contractions. E. Remak has seen and described the same phenomenon in atrophic spinal paralysis, and, in consequence, makes use of the term 'faradic reaction of degeneration.' Leegaard also states that he has obtained a notably sluggish contraction by exposing the degenerated muscles in a rabbit and exciting them with the faradic current. I have myself lately caused to be published (by Vierordt) a new case of neurotic paralysis of the ulnar, in which, with faradic excitation, direct and indirect—the latter being applied to the ulnar above the wrist-joint—I obtained a visibly sluggish contraction in the hypothenar, which disappeared slowly after the cessation of the current. Further, on exciting the ulnar above the wrist, adopting all due precautions, I obtained with strong currents a notably sluggish KCC, while direct excitation of the muscles produced but a slow and feeble ACC. Moreover Kast, in a case of atrophic paralysis of the leg (probably disease of the anterior roots), has found the intermediate form of the reaction of degeneration and markedly sluggish contraction with direct and indirect faradic excitation, while galvanic excitation of the nerve is said to have produced lightning-like contractions. I have myself had an opportunity of observing and studying this phenomenon as it was extremely well displayed in a case of chronic anterior poliomyelitis occurring in a child of six years, and I have also recorded it in cases of radial and facial paralysis. In all the partial reaction of degeneration was present, but in all, whatever the nature of the stimulus—whether faradic or galvanic, opening or closure, primary or secondary interrupted current, whether the ordinary spring was used or a special interrupting contrivance, and finally even with a mechanical stimulus—*the contractions produced by excitation of the nerve were always of a markedly sluggish, tonic character*, and always, too, *direct faradisation* of the muscles yielded only a sluggish contraction. This peculiarity in the contraction depends probably upon changes in the muscular fibres themselves. Their nutrition is impaired, so that the short, lightning-like contraction cannot be produced; while, on the other hand, excitation of the nerve even with instantaneous or passing stimuli (faradic current) is effected. This state would seem to be intermediate between those which are marked by the complete and partial forms of the reaction of degeneration and may be regarded as a transition between them. The name 'faradic reaction of degeneration,' which E. Remak has proposed for this condition, is not sufficiently expressive, and I have proposed instead that it be called the 'partial reaction of degeneration with coincident (or else indirect) sluggish contraction.' Its diagnostic import is almost the same as that of the partial reaction of degeneration, and from the point of view of prognosis it may be taken as holding a place intermediate between this and the complete form. It may be present at the stage of degeneration or of repair, or may endure more persistently for a longer time in the course of the disease. The discrepancies between the results obtained from clinical observations and from experiments upon the lower animals, as well as between the conclusions of different observers, which arose so frequently in the investigations of the various problems, appear to vanish in the most satisfactory manner with the progress of later researches, conducted with the utmost care by Leegaard and Bastelberger. The statements of Vulpian, who would have us believe that there can be no question of a constant increase of excitability and the ascendency of the ACC, hardly call for comment. They are in direct opposition to the experience of the other observers who have devoted themselves to their subject in a far more zealous and conscientious manner. Equally false is the assertion of Goldschmidt, according to whom the muscles of the rabbit when exposed exhibited quite a different reaction to that which followed excitation through the skin. The fallacy has been exposed by Bastelberger, who worked in the same laboratory. The latter found no distinction between covered and exposed muscle, and he further demonstrated, in opposition to Vulpian, an almost invariable rise in galvanic excitability and the uniform ascendency of the ACC.

There is, therefore, a very satisfactory agreement between clinical facts and the information derived from experiments, and if discrepancies occasionally arise, this is no more than might be expected. A man is not a rabbit; and even as seen amongst rabbits the results are not always the same. At any rate, in all important particulars there is an ample concurrence of testimony.

The theory of partial RD, put forth by Wernicke, does not seem to me to meet all its manifestations. According to him this condition may be thought to depend upon a partial degeneration of the nerve fibres and the muscular fibres connected with them, whilst some of these remain unaffected. This view will hold for certain forms of disease, as, for instance, limited atrophies without paralysis, progressive muscular atrophy, and pareses of slow progress. But for the more pronounced conditions of complete paralysis with the partial RD (as in the intermediate form of rheumatic facial paralysis) it does not seem to me to be tenable, and for this reason: On the one hand we have the contrast between the complete paralysis, the almost unimpaired excitability of the nerve, and the highly developed reaction of degeneration in the muscle; on the other the proportion is commonly absent, which, according to Wernicke, we should expect to obtain, between the diminution of excitability in the nerve and the modification of galvanic excitability in the muscle. These changes in the excitability of the nerves and muscles, if they depend only upon the *number* of fibres engaged, must bear a definite relation to one another. If many fibres are degenerated the reaction of degeneration should be pronounced and spread through the entire muscle, at the same time that the normal contraction produced by the nerve should be slow and retrograde: if only a few fibres are engaged things will be reversed—slight diminution of excitability in the nerve and feeble reaction of degeneration in the muscle. But the truth is very far from this. I have devoted much attention to this condition, and I have found in many instances that the *entire* muscle responded vigorously to both forms of stimulus: to the direct excitation with a protracted and sluggish, to the indirect with a short and lightning-like, contraction. It follows that the muscle fibres have all or nearly all undergone structural change, and that the nerve fibres are all, or nearly all, free from it. It is the same condition as we find at a certain stage of repair when excitation of the nerve causes a short and rapid contraction, while direct excitation produces a slow and altered movement. Further, I consider Wernicke's theory incompatible with the occurrence of a marked reaction of degeneration in muscles which have not been paralysed or even weakened to any appreciable extent.

LECTURE XI.

4, The Myotonic Electrical Reaction—5, Less Common Quantitative and Qualitative Changes in Electrical Excitability—(*a*) Increase of Secondary Excitability (Reaction of Convulsion)—(*b*) Diminution of Secondary Excitability (Reaction of Exhaustion)—(*c*) Qualitative Modifications of the Law of Contractions occurring in Motor Nerves—(*d*) Different Behaviour of the Nerve with Faradic and Galvanic Currents—(*e*) Latent Period in the Faradic Excitation of a Muscle—(*f*) Diplegic Contractions—*B*, Electrical Diagnosis of Sensory Nerves—Anomalies of Farado-Cutaneous and Farado-Muscular Sensibility.

4. THE MYOTONIC ELECTRICAL REACTION.

IN the so called *myotonia congenita* (Strümpell), or Thomsen's disease, there occurs a series of changes in the electrical excitability which I have lately closely studied, and for which I have proposed to employ a separate name, since they possess many characteristics of their own and differ somewhat from other reactions.

You know that in this remarkable affection there is a peculiar derangement confined to the muscular system, such that the first voluntary movement after long repose is exaggerated and protracted, and rendered to some extent inefficient by tension and rigidity in the muscle, which, however, entirely disappears with continued action and gives way to free movement. Moreover, if a sudden and energetic contraction be caused in the muscle a condition of tonic rigidity is produced and persists for a long time (10 to 30 seconds) after the voluntary stimulus is withdrawn (*persistence of voluntary contraction*). The affection is usually congenital and hereditary—running in families like progressive muscular dystrophia and Friedreich's ataxy.

The muscles exhibit an athletic development amounting to marked hypertrophy, are often strikingly hard and firm to the touch, and show a high degree of mechanical excitability, so that when struck they give a vigorous but persistent (15 to 30 seconds) and slowly disappearing contraction (*persistence of mechanical contraction*). The motor nerves, on the other hand, display rather a diminished than increased excitability.

Electrical investigation shows us, as in the reaction of degeneration, a different condition in the nerve and muscle. The motor nerves act on the whole in a quantitatively and qualitatively normal manner to both the faradic and galvanic currents, except that KCT occurs comparatively early. Only strong, concentrated currents (the secondary faradic current with free spring interrupter, or labile galvanic currents) will produce a tonic and notably persisting contraction when transmitted through the nerve. But even the strongest separate opening shocks will only produce a short, lightning-like contraction. The *muscles*, on the other hand, display in respect of both currents a very lively excitability. Faradic excitation with currents of moderate strength gives a peristent contraction (*persistence of the faradic contraction*). But here again with separate opening shocks we get only very short contractions.

To galvanism, on the other hand, the muscles are very little excitable—exhibit only closing contractions, and the anode and kathode preponderate indifferently. But the most remarkable phenomenon is the extraordinary *sluggishness and long persistence of the galvanic contraction.* The minimum excitation, to be sure, yields with the kathode, but hardly ever with the anode, a short contraction. But with every increase in the current strength the characteristic sluggishness becomes apparent. If the electrode is placed lightly upon a muscle, or the circuit suddenly closed, there sets in a slow and gradual shortening, which, according to the size of the electrode and the extent of the muscle under excitation, either throws the part into deep pits and furrows or causes the muscle to stand out bodily in a slowly developed contraction, which determines the characteristic sluggish movement of the limb. This condition remains for a long period (5 to 30 seconds) after the stimulus has been removed, and disappears again gradually. It suggests what may be seen in some tenacious viscid substance, when its surface is broken and the inequalities are allowed slowly to subside again. Finally, the stabile action of the galvanic current is attended by a very remarkable phenomenon: this is the occurrence of rhythmical undulatory contractions, which uniformly proceed from the K to the A. It is best seen when the electrodes are applied not directly to the muscles but close to the attachments of their tendons—as, for instance, in the flexors at the forearm when the electrode is held in the hand; in the vastus externus or internus when it is placed at the outer or inner side of the patella, the indifferent electrode being at the sternum or behind the neck. As these contractions follow upon one another in waves of varying size, and at intervals which differ in different cases, they produce a very beautiful and striking effect. They occur especially when a current of considerable strength has been passed through the muscle, and after the cessation of the tumultuous movements which first ensue. As yet I have seen the phenomenon only in the flexors of the forearm, in the vasti, and in the biceps brachii. In the latter muscle it was typically displayed. Similar contractions of an undulatory character, but without rhythm or uniformity, may also be induced in the separate muscles by faradic excitations.

These peculiarities, which are manifested essentially by a variation in the mode (sluggish and persistent) of contraction, and are displayed, as we have shown, especially by direct excitation, are of great importance in the diagnosis of Thomsen's disease. They extend to the entire voluntary muscular system, including the muscles of the tongue and those of expression and mastication, and whilst they are not very obvious in the facial muscles they are very clearly displayed in those of the tongue.

As to whether these phenomena are intimately related with the structural changes which I have established in the excised muscle—excessive hypertrophy of the muscle bundles, with considerable cell proliferation in the sarcolemma, transverse striation and interstitial connective tissue not notably altered—it would be premature to decide. But to my mind it is in the highest degree probable that, as in the RD, so also in the myotonic reaction, structural changes in the muscle are among the essential conditions of its manifestation.

The myotonic reaction is not always easily recognised. It bears a certain resemblance (especially in the sluggish contraction and the occasional preponderance of the A) to the RD. With the complete RD, however, it cannot be confounded, since in the latter the excitability in the nerve is entirely lost.

But it may be mistaken for the partial RD and especially for the form 'with accompanying sluggish contraction' (see p. 210). The two conditions are to be distinguished thus: In the myotonic reaction separate opening shocks always cause a rapid shortening; excitation of the nerve acts in a like manner; the characteristic slowness of contraction is of a somewhat different kind—more intensive; the persistence is quite conclusive; there is no paralysis, no atrophy, but rather hypertrophy; the condition extends to the entire body, and is not seen to change while the case is under observation. By attention to these facts the differential diagnosis is rendered easy, as a rule. And in the same way it may be effected with even greater certainty for tetanus, pseudo-hypertrophic paralysis, and true muscular hypertrophy; so that I need not enter into the details of the process for each.

5. LESS COMMON FORMS OF QUANTITATIVE AND QUALITATIVE MODIFICATIONS OF ELECTRICAL EXCITABILITY.

In this chapter I propose to give some account of the various observations and admitted facts concerning the more rarely occurring electrical reactions of every kind—without reference at present to their practical import. They have not yet been invested with scientific value, and since their existence and importance are still questioned we cannot draw from them any useful inferences in diagnosis.

(*a*) Under the name of the *Reaction of Convulsion*, Benedikt has described a qualitative modification of excitability, such that after a short action of the current there occur contractions much more vigorous and energetic than usual, which may even become convulsive. This is probably what Brenner meant by the *secondary augmentation of excitability*. He understood by this term a condition induced in the nerves by the current itself capable of being expressed in numbers for the estimation of its degree. If, for instance, in a given nerve the KCC first occurs with 16 cells, but after a somewhat prolonged action of the current is produced by 12 cells, then 16 cells express its primary and 12 its secondary excitability. The greater the difference between these numbers (as in the preceding example the second might have been 10, 8, 6)—that is, the fewer the cells or the weaker the faradic current needed eventually—the greater the degree of secondary excitability, and *vice versa.* Unfortunately, accurate investigations are still wanting to show what part in the production of this secondary excitability must be assigned to changes in the resistance brought about by the action of the current. These changes, as I have already pointed out to you, are known to be very considerable, and doubtless they are chiefly instrumental in bringing about this phenomenon. This, too, is the opinion of E. Remak, and it was because he was conscious of the difficulty that Brenner himself has attached but limited importance to his discovery.

Cases, however, are sometimes met with which really exhibit some such modification of excitability as this—as, for instance, certain psychoses, cerebral tumours (Petřina), many affections accompanied with cramps, chorea, tetanus, &c. But the phenomenon has not yet been accorded much importance.

Benedikt also points out that by opening and closing the circuit he produced not a simple contraction, but a clonic spasm —opening and closure clonus—which doubtless was not without a corresponding physiological state. Possibly we should class with these the peculiar reaction which Väter von Artens has described under the name of 'electrical palmospasm,' and which nobody appears to have observed since. In a case of progressive muscular atrophy of the right upper extremity, with a moderately strong faradic current, after removal of the electrode, or with a moderately strong galvanic current at the period of opening, when applied to the nerves of the arm there took place in the forearm and hand violent cramp-like movements of rotation and oscillation, and alternately of flexion and extension and sidelong distortions. These spasms endured for two and a half minutes, and could not be stopped by the exercise of the will. The condition lasted for some months.

(*b*) The converse of the previous anomaly is a diminution of secondary excitability, the *Reaction of Exhaustion*, which is perhaps identical with what Benedikt has described more lately as the *Lückenreaction.* If, at a time when the nerves and muscles in their unimpaired condition show no sign of exhaustion worth speaking of, they are submitted to the frequent and long-continued action of a stimulus which is at first efficient, this in certain pathological states will cease to be so, and the secondary excitability will be expressed by a greater instead of a less current strength. We have here, then, a *negative increase of excitability* due to the current itself, and brought about by a sort of rapid fatigue and exhaustion of the nerve. Thus, for instance, the minimum contraction occurs at first with 180 millimetres distance of coils, and after a short time only when the distance is 160 millimetres; and again the distance must not be greater than 140 millimetres to produce it. Or the first KCC occurs with 16 cells. By repeating the KC the contraction is made to grow weaker and weaker, and finally disappears; and then 18 or 20 cells are needed to develop it. The greater the degree of exhaustion, the longer will be the time necessary to restore the muscle or nerve to its normal vigour (Brenner).

This condition, like the previous one, has been but seldom seen, but it is at all events the more common of the two. Its determination also is less exposed to errors contingent upon inconstant and unreliable instruments, and can be more easily effected without the agency of the galvanometer. It has been observed in paralysis from cerebral disease, in progressive muscular atrophy (Benedikt), and in apoplectic hemiplegia (Brenner). O. Berger demonstrated it by faradic excitation in a case of muscular hypertrophy, and Salomon in one probably of chronic anterior poliomyelitis, where it supervened upon the slow and inappreciable lowering of faradic excitability in the muscles, as a transition to the reaction of degeneration. He also found it in a case of long-standing sciatica. I have myself observed it with the galvanic current in a case of paralysis agitans, where it coexisted with a diminution of galvanic excitability. But these changes are of no great practical or diagnostic value.

(c) *Qualitative Modification of the Law of Contractions in a Nerve.*

Qualitative changes in the law of contractions are as uncommon in the nerve as they are frequent in the muscle. The observations that have been made upon this subject are few and in some respects unsatisfactory. Brenner asserts that with all his extensive experience he has never seen qualitative modifications of contraction having their origin in the nerve.

Leegaard has seen on one occasion ACC > KCC, and once also KOC > AOC in a short quick contraction. And Stintzing observed the same phenomenon once after stretching of the sciatic nerve. For my own part I have found in the course of a careful and accurate investigation in two cases the ACC appearing earlier than the KCC in the ulnar, while the contraction—short and quick as lightning—was of a purely nervous character. They were both cases of chronic spinal disease. One was a tabes dorsalis, and here, in the two ulnars, with weak currents the ACC was developed earlier and of a more vigorous character than the KCC (with 6 and 10 cells); whereas with greater current strengths (12 to 16 cells) the KCC prevailed more and more. In the other instance precisely the same thing occurred. It was a complicated spinal affection: spastic paralysis of the legs, paresis with exaggerated reflexes in the arms, sensory derangements, ataxic symptoms, &c., confined to the left arm. In the left ulnar alone there was premature and over-energetic manifestation of the ACC with weak currents, while the stronger exhibited the normal condition. More precise investigation, consequently, showed:

With	10	cells	ACC′ KC–
,,	12	,,	ACC >KCC
,,	14	,,	ACC′ >KCC
,,	16	,,	ACC′ =KCC′
,,	18	,,	KCC″>ACC′, AOC
,,	20	,,	KCC″>ACC′, AOC, KOC

These results were uniformly obtained in repeated examinations. I should also mention that the KOC appeared almost synchronously with the AOC. At length the same phenomena occurred in the radial and median of the left side. In the nerve trunks of the right side as in both peroneals galvanic excitability was of normal quantity. Petřina has demonstrated a similar ascendency of the ACC in cerebral tumours.[1]

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[1] In a case of progressive muscular atrophy Bernhardt, exciting the ulnar nerve, obtained contractions, which were all of normal rapidity, in the following order: AC, KO, AO, KC.

In another case of long-standing disease, probably sclerosis of the cervical part of the cord, accompanied with spastic paresis, rigidity of the right arm, &c., I have clearly proved the ACC > KCC in the ulnar nerve, where also the AOC was usually the first to appear. Chvostek would seem to have seen a similar phenomenon in the nerves of the arm in a case of tetanus, viz. AOC as the earliest reaction.

We must also regard as a qualitative anomaly of the law of contractions the fact established by Rumpf, that the AOC occurs earlier and more readily in nerves whose connection with nerve centres is broken. This fact, which was first discovered by experiment, has been verified in the human subject by Rumpf in connection with appropriate cases of motor paralysis of recent origin. I give two of these :

1st. *Paralysis of radial, caused by crutches.* 15 *days.*

	Healthy Side.	Affected Side.
KCC . .	with 11° deflection of needle	12° deflection of needle
ACC . .	„ 29° „ „	30° „ „
AOC . .	„ 35° „ „	25° „ „

Hence increased anodic excitability.

2nd. *Paralysis à frigore of radial.* 8 *days.*

	Healthy Side.	Affected Side.
KCC . .	with 21° deflection of needle	33° deflection of needle
KD > . .	„ 38° „ „	37° „ „
ACC . .	„ 36° „ „	35° „ „
AOC . .	„ 32° „ „	23° „ „

Hence diminished kathodic and increased anodic excitability.

But we cannot determine this state of things in all cases of recent paralysis, and there is need of further investigations in this direction to establish it.

(*d*) *Differences in the Behaviour of the Nerve to the Faradic and Galvanic Currents respectively.*

When the RD was first discovered most observers thought that the motor nerves, like the muscles, behaved differently to the faradic and galvanic currents. I was the first to show clinically—and experiment has borne me out—that this was not so, and that in the RD the nerve reacts in precisely the same way to both currents—contrasting, in this respect, with the muscle. And this seemed to be true under all circumstances, or at all events in the numberless investigations of the matter that have been made. No departure from the rule has been witnessed in a man who exhibited the RD.

Nevertheless there are isolated facts which go to prove that this modification of excitability, theoretically possible, does really occur in the nerve. I obtained from the crushed nerve of the frog the first experimental evidence that bears upon the subject—loss of faradic excitability in the nerve; galvanic excitability retained, but diminished for currents of short duration. To the comments which I made upon this discovery I am disposed still to adhere. The fact that Cyon claims to have seen something analogous in one instance in the crushed nerve of the rabbit is not sufficient to induce me to regard the thing as completely established. The statements of Leegaard on the subject are equally inconclusive.

Bernhardt has quite lately established, in man, a notable diminution (20 to 30 millimetres) of faradic, and a considerable increase (6 to 8 cells) of galvanic, excitability, occurring in the ulnar nerve in one of the later stages of traumatic ulnar paralysis. Notwithstanding that the resistance was overlooked the fact seems sufficiently definite to be recorded. But the case involved the RD, in spite of the incomprehensible and repeated assertions of the author that it was absent. For, according to his published account, there was in the muscles supplied by the ulnar an increase of galvanic excitability, a preponderance of the ACC, a halting and sluggish contraction, and at the same time faradic excitability was lessened or entirely lost. This observation, then, though it has not hitherto been repeated, tallies with the rare facts derived from experiment to which allusion has been made above. It is to be desired that further and more accurate investigation may be undertaken to show definitely the existence in motor nerves, too, of a diminished excitability with currents (faradic) of short duration and increased excitability with those (galvanic) of long continuance.

We have been long acquainted with this quality in the muscle, and it has been referred to physical causes. Adamkiewicz, however, has lately felt the necessity of assuming an *isogalvanic* and *isofaradic* muscular reaction. This view does not seem to me to be sufficiently borne out by facts to call for much comment here. But I am unable to see by what process of reasoning Adamkiewicz has adopted as correct, and in conformity with phenomena observed in the muscles, the long exploded theory of Eulenburg that 'there are in the motor nervous apparatus specific energies for galvanic, faradic, and voluntary excitability.' Has it not rather been sufficiently proved that nerves and muscles behave quite differently in this respect?

(*e*) *Latent Period in the Faradic Excitation of the Muscle.*

With the instrument constructed by Marey, M. Mendelssohn has estimated the latent period in excitation of the muscles of the living human subject. He found that it varied, with an average length of 0·006 to 0·008 second, depending, on the one hand, on the intensity of the current used, and on the other on the excitability and contractility of the muscles. In pathological conditions there was much variety in the length of this latent period. Here, too, it was in inverse ratio to the excitability and contractility of the muscles. It was uniformly less in those that were rigid and greater in presence of trophic muscular derangements. Accordingly Mendelssohn observed a shortening (to 0·003 second) of the latent period in hemiplegias with rigidity, spastic spinal paralysis, chorea, &c., and, on the other hand, it was protracted (to 0·02 to 0·04 second) in hemiplegias attended with atrophy, progressive muscular atrophy, lateral amyotrophic sclerosis, tabes at the stage of paralysis, and atrophy, and also in hysteria (0·009 to 0·018 second). Thus there is opened a new field for investigation in electrical diagnosis, such as merits somewhat more careful attention. It would be of great interest to search more closely the condition of the latent period in the RD.

(*f*) *Diplegic Contractions.*

By this term R. Remak for the first time directed attention to certain remarkable phenomena of reaction which are exhibited in rare cases and with a special disposition of electrodes conveying a galvanic current. Thus, if the positive electrodes, shaped like a button, be placed in the mastoid fossa, or even on the nearest accessible part of the neck, with the large flat negative electrode between the shoulder-blades, or placed lower down against the vertebral column at the other side, peculiar movements, more or less lively and extensive, take place in the arm opposite to the anode, even while the electrodes are retained in position. These contractions are said to be absent when the position of the electrode is reversed and even when the negative pole is removed to the neighbourhood of the neck; and Remak has called them *diplegic*, because they are supposed to be produced by the meeting of (the currents from) two points remote from one another. Remak thought that these contractions were of a reflex nature, and looked upon the superior cervical ganglion as their principal source, but later he ascribed them to the simultaneous excitation of the two sympathetic ganglia. This is the reason why the two poles must be separated some distance from one another. By administering strychnine these diplegic contractions can be made more apparent. Remak observed them especially in progressive muscular atrophy and arthritis nodosa; and he attributed to this diplegic disposition the remarkable cures which galvanic treatment has effected in these diseases.

Later observers have seldom seen these phenomena, and thought them of little consequence. Moreover, it would seem as if they were not always dealing with the same thing. Drissen found diplegic contractions in a vasomotor neurosis, and in paresis of the nerves of the arm; Mor. Meyer met with it in the paralysis of arsenic poisoning; Fieber, in lead palsy, apoplectic paralysis, &c.; Eulenburg, in lead palsy; Eisenlohr, as a symptom of bulbar paralysis—but with the poles reversed. For my own part I have seen ill-marked diplegic contractions in a case of muscular atrophy; also in one of atrophic paralysis of the arm, with derangements of sensibility and nutrition in the skin (neuritis? spinal neuralgia?). In this they were clearly seen only after the administration of strychnine; and, when the electrodes were placed to the right, somewhat lively contractions (strong and fibrillar) were produced in the left hand. In a third case of atrophy of the muscles of the hand and forearm, of obscure nature and stationary in the character, there occurred spasmodic rhythmical contractions in several fingers and the muscles of the forearm, with diplegic excitation in either direction, whereas when the brachial plexus was directly excited the muscles remained at rest.

The instructions given by other observers as to the best way to produce these movements are somewhat at variance with the teaching of Remak. Fieber has been able to effect them with the faradic current as well; and claims to have established, by his experiments on rabbits, that the superior cervical ganglion is their point of departure. Mor. Meyer brought them about with other points of application (epigastric fossa, sternum), while Eulenburg witnessed them with crossed or even unilateral application of a stabile or labile current, at any part of the trunk indifferently.

He rejects the theory that would connect the phenomenon with the sympathetic, but fails to supply a better in its place, since he attributes it to an exaggerated excitability of the muscles and reflex centres. Benedikt has seen the contractions with a current in the other direction, and with the faradic current. If we may credit his observations, they occur in all cases on that side on which the sympathetic is excited; and he finds them especially in all cases where reflex excitability is exalted, with pressure on the sympathetic in the neck—that is to say, in nearly all neuroses. Here, then, we have a profusion of conflicting statements, which for the most part are but indifferently founded, and from which it is impossible to derive a very clear notion of 'diplegic contractions.' Of late they have been, perhaps undeservedly, neglected. They have not secured any great importance either in diagnosis or therapeutics. The great results achieved in the latter department by Remak will bear quite another interpretation.

In this connection, of reflex phenomena, undoubtedly belong the 'galvano-tonic reflexes,' which Remak has studied so closely, and also the contractions which take place with galvanic excitation in the arm or leg which is not excited (in hemiplegia, tabes, &c.), and which are supposed to depend upon the *centripetal* action of the current. These reflex and similar contractions since the time of Remak have been noticed only by a very small number of observers (Braun, Benedikt, &c.), and in no case have they been studied very carefully. In all probability they are but unusual forms and degrees of reflex excitability. These considerations have no practical importance.

B. MODIFICATIONS OF ELECTRICAL EXCITABILITY IN SENSORY NERVES.

In contrast to the abundant information we possess with reference to the motor nerve structures in electrodiagnosis, is our great poverty in such knowledge concerning the sensory nerves. In speaking to you of the electrophysiological phenomena of these nerves, I was compelled to admit that we are in possession of but little useful information; but the case is perhaps worse in connection with pathology. In reality we are acquainted only with a state of *simple increase* (hyperæsthesia) and one of *diminution* (anæsthesia) of electrocutaneous sensibility, more or less analogous to the other sensory derangements in the skin, especially to that of pain. These disorders arise in pathological conditions of the most various kinds, and they are determined by the methods pointed out before (Lect. VIII. p. 155). Electricity is of use here only as a means of examining the functional condition, not, as in the case of motor nerves, for estimating changes in the excitability of the conducting structures, which latter are quite apart from the disorder of function and find their application in diagnosis. It is to be regarded rather as a more or less efficient subsidiary in investigation, than as a source of certain and necessary information for the understanding of pathological processes. Thus we can tell by its means, in the different peripheral and central diseases, whether electrocutaneous sensibility is lowered or increased, and to what extent. And, especially in unilateral disease, we can determine readily and with certainty the most inconsiderable changes by means of the faradic examination—often, indeed, better than by the other methods of investigating the condition of sensibility, in which the stimuli cannot be so nicely adjusted. I submit, as an illustration, a case of traumatic injury in the spinal column, followed by slight weakness and anæsthesia of the left leg, which latter was very well exhibited by the electrical method detailed above (p. 158).

A Man, aged 24.

Place of Excitation	Minimum		Pain		Deflection of Needle with 12 Cells and 150 Resistance
	Right	Left	Right	Left	
Cheek	230	205	155	164	12°–16°
Neck	200	195	152	152	3°–4°
Forearm	180	165	150	135	3°–3°
Ends of fingers	144	140	110	112	5°–4°
Thigh	180	142	138	119	3°–2½°
Leg	195	142	145	100	2°–2°
Soles	105	77	75	52	4°–5°

Whereas, therefore, there were no differences to speak of in the upper part of the body, these were very marked in the lower extremities, at the expense of the left side. And this the numbers sufficiently point out.

In tabes dorsalis, where an accurate means of investigating the condition of sensibility is so desirable, it has been found that electrocutaneous sensibility is always proportional in degree and extent to the sensibility to pain, and that where analgesia is present without impairment of the sense of touch the minimum faradic sensation and the minimum faradic pain are produced only by very much stronger currents.

In many cases faradic cutaneous sensibility appears to be simply lowered throughout the body ; and the difference in the distance between the coils for the minimum sensation and for pain is not much greater in ataxics than in healthy persons (Drosdoff). Hence the expectation that I once entertained that the faradic minimum sensation would vary with the sense of touch, and that in consequence we should have in the faradic examination an adequate test for the estimation of analgesia, has not been realised. But faradic examination enables us to discover certain anomalies which might otherwise easily escape us. I will mention but one case as an example. (See table opposite.) A comparison with the normal tables will serve to show clearly the general diminution of farado-cutaneous sensibility.

I have seen as yet but one case of tabes dorsalis in which there was an evident faradic cutaneous analgesia, while the figures for the minimum sensation were hardly at all reduced. The patient retained the sense of touch and temperature tolerably unimpaired, side by side with complete analgesia.

Tabes Dorsalis, in a Man, aged 36 *years* (February 14, 1879).
(The figures for the two sides correspond very closely, and are here combined.)

Point Excited	Minimum in Mm.	Pain in Mm.	Deflection of Needle with 10 Cells
Cheek	150	120	26°
Neck	154	110	20°
Arm	154	110	12°
Forearm	152	108	7°
Dorsum of hand . . .	144	103	10°
End of fingers . . .	90	70	3°
Abdomen	136	100	16°
Thigh	128	85	5°
Leg	120	78	5°
Dorsum of foot . . .	112	70	4°
Soles	85	45	10°

The figures expressing the minimal farado-cutaneous sensations in his case vary between 203 mm. (cheeks), 170 (arm and forearm), 163 (finger ends), 177 (thigh), and 150 (sole), whilst throughout the entire body, the face included, he did not experience the slightest pain even when the coils of a powerful sledge apparatus were completely overlapping. Decidedly this was a sufficient analgesia. Still even in tabes such a phenomenon is exceptional. It would be interesting to prosecute further the study of these problems, but we require for the purpose a more perfect method, and a broader physiological basis for the estimation of results. All the researches that have hitherto been made have failed to secure for themselves a position in electrical diagnosis.

There have been published of late some observations which at least afford a prospect of further discoveries in connection with the electrical diagnosis of sensory nerves. M. Mendelssohn found in a number of tabetics that at the skin (and not, as it would seem, at the sensory nerve trunks themselves) the ACR was greater than the KCR, that in some there was no opening sensation, and that in others the KCR was absent and only the ACR could be obtained. We have here, therefore, anomalies of the sensory formula (v. sup. p. 96) which Mendelssohn would do well to compare with the RD in muscles. They seem to me rather to be analogous to the qualitative modifications of the law of contractions in motor nerves (v. sup. p. 218).

The anomalies of electrical sensibility of the skin (as before, not of the nerve branches in the skin)—diminution of faradic, increase of galvanic excitability, and the like—which Gerhardt has found in herpes-zoster, and to which he has applied the term 'sensory reaction of degeneration,' require still to be established by more accurate methods, in which the resistance to the current must be estimated and regard had to possible differences between the sensibility of the skin itself and that of the nerve trunks, the contigent electrolytic action of the current, &c. At any rate, these observations do not seem to me to prove that there is a reaction of degeneration in the sensory nerves in every case of shingles.

At the present day we hear nothing of the investigation of *farado-muscular sensibility*, to which Duchenne attached so great an importance in diagnosis. This may be suppressed in pathological conditions without at the same time any loss of farado-cutaneous sensibility (in hysteria, Duchenne), but as a rule there coexist derangements of sensibility in the skin too. Often again farado-muscular sensibility is retained side by side with cutaneous anæsthesia, as, for instance, in a unilateral spinal lesion (Lanzoni). But these facts, however interesting from the point of view of pathology, have no significance in diagnosis.

LECTURE XII.

C, Electrical Diagnosis of the Nerves of Special Sense—1, Optic Nerve and Retina—2, Auditory Nerve and the Organs of Hearing—(*a*) Simple Galvanic Hyperæsthesia—(*b*) Hyperæsthesia with Modification and Inversion of the Normal Formula—(*c*) Qualitative Anomalies without Hyperæsthesia—(*d*) Torpor—3, Nerves of Taste—Electrical Diagnosis of Vasomotor Nerves—Of the Sympathetic—Of the Pneumogastric—Of the Central Nervous System, &c.

C. MODIFICATIONS OF ELECTRICAL EXCITABILITY IN THE NERVES OF SPECIAL SENSE.

1. It is with great reluctance that I am compelled to admit, with reference to pathological conditions of the electrical excitability of the eye, that hitherto there have been but very few researches and discoveries connected with the Optic Nerve and Retina, notwithstanding that this, perhaps more than any other, organ, by reason of its accessibility, the frequency and importance of its nervous affections, and its intimate connection with many serious disorders of the central nervous system and other parts of the body, would seem to merit the closest investigation, and to afford a promise of the most ample results. It

will be easily conceived that there are here many facts of interest and importance to be discovered: as to whether, for instance, qualitative modifications in the law of optical excitation, such as changes of colours, of the opening and closure reaction, &c., are met with in disease of the retina and optic nerve; and to what extant quantitative changes obtain in the different forms and phases of amblyopia. It would be interesting in diseases of the transparent media of the eye to determine whether the excitability of the retina and optic nerve is unaffected, and to ascertain the nature of the luminous sensations in hemianopia, central scotomata, &c., and finally to learn whether in peripheral affections of the retina and optic nerve luminous and galvanic sensations continue to be produced by excitation of the central fibres in the nerve trunk or optic tract, or, as it may be, in the brain at certain parts of the cortex. This is a question of the highest physiological importance, and certainly it is not without its practical interest.

Of all this, unfortunately, little or nothing has been ascertained. It has been long known, indeed, that the galvanic reaction of the optic apparatus is lessened or lost in amaurosis, optic atrophy, &c.; but Neftel, proceeding upon Brenner's mode of exploration, was the first to give any detailed account of the process. He found in a case of hemianopia a defect of the galvanic colour disc, sufficiently characteristic of the affection, and the same thing is said to occur in detachment of the retina. He found as a rule that the galvanic reaction of the eyes varies with the visual power, and he further assumes a pathological *hyperæsthesia* (ready excitability) and a *torpor* (difficult excitability) of the optic nerve. But the two cases cited in support of this view are not conclusive, since they were examined without a galvanometer. In unilateral hysterical paralysis Neftel affirms that he has often failed to find the galvano-optical reaction even in the eye of the sound side. M. Rosenthal, on the other hand, found this reaction diminished on the side of the hysterical anæsthesia in proportion to the high degree of amblyopia present.

I have myself availed of the material which occasionally presented itself to undertake researches which still I must regard as insufficient. They are attended with very great difficulties, and it is especially in cases of unilateral disease that a positive result is almost unattainable, because the sound eye by means of its great excitability is readily affected by the shocks, and its reactions seriously complicate the investigation. I append a brief outline of some of my cases.

1. *Optic Neuritis* (bilateral), followed by atrophy of the optic nerve; amblyopia (fingers at 6 and 2 feet).—On both sides a feeble galvanic sensation (whitish), without any sense of colour, and no difference between the two poles at opening or closure.
2. *Fracture of the Skull.*—Left eye, complete amaurosis. Right eye, amblyopia and temporal hemianopia. No galvanic reaction in left eye. In right galvanic sensations of light confined almost exclusively to the median (left) half of visual field.
3. *Cerebral Tumour.*—Complete bilateral amaurosis; at first papillary congestion, later whole atrophy of optic nerve. With electrode B at neck, when A is placed on the right temple or the right or left closed eye, the luminous sensation occurs only in right with KC and AC. If, then, A is placed on the left temple there occurs with the luminous sensation in the right eye a feeble one also in the left. (Here the explanation is obscure. Does it depend upon the tract excited?)
4. *Amblyopia of Right Eye*, from retrobulbar neuritis.—A lively galvanic reaction in the left eye. In the right, with 6 or 8 cells, no luminous sensation. A few months later, with distinct improvement of the visual power, the right eye reacted as evidently but more feebly than the left.
5. *Tabes Dorsalis, with Complete Amaurosis*, from atrophy of optic nerves.—Had previously had a perceptible galvanic sensation of light, which now was absent even with a transverse current through the mastoid apophyses, and with excitation of the supramarginal gyrus by means of a large electrode (to excite the optic centres in the cortex), and with a current so strong as to produce a reaction in the auditory with moderate hyperæsthesia of that nerve.
6. *Bilateral Amaurosis*, caused by a pistol bullet penetrating the right temple.—In the left, a trace of vision; in the right, total blindness. Sense of smell lost. On the right side, with 4 or 6 cells and galvanic excitation, as direct as possible, an evident sensation of light. On the left, a feeble sensation of light with 2 cells, strong with 4 or 6 cells. Later, marked improvement of vision.

I purposely abstain from drawing any conclusions from so small a number of observations. But it is my belief at all events that there is here a field for research which would be by no means unproductive and which yet remains open. I would recommend it to the attention of oculists.

2. We are much more fortunately situated with reference to the pathological reactions of the nervous mechanism of hearing—of the Auditory Nerve, in short. Here, thanks to the efforts of Brenner especially, an abundance of interesting information has been obtained, and it is from pathological conditions that we derive the accurate knowledge we possess of the normal reaction of the auditory nerve. It is, in fact, especially amongst those suffering from aural affections, and in whom the nervous mechanism of hearing often reacts with an almost marvellous readiness and ease to the galvanic current, that we can conduct investigations without any annoyance to the patient and obtain the most striking results. And these results have already proved of great practical utility; for it has been shown that in a definite series of cases the deductions from electrical examination directly suggested the form of electrical treatment and the method to be adopted in applying it. For the most part they were cases of obstinate tinnitus, that resisted every other means of cure, but succumbed to galvanism in a most brilliant manner, as you will learn later more in detail.

At any rate I would urgently impress upon aural surgeons the expediency of a galvanic examination in every case of serious and chronic disease of the ear. In a very considerable number of instances the most interesting results are obtained, even though it is not always possible to bring about the desired therapeutic ends.

In the course of his researches Brenner found a large number of anomalies in the galvanic reaction of the auditory, and these have been confirmed, and perhaps the subject completed, by many subsequent observers (Hagen, Moos, Erb, Hedinger, Erdmann, Eulenburg, &c.) By far the most frequent of these anomalies are—

(a) *Simple Galvanic Hyperæsthesia of the Auditory.*

This is characterised by the more or less ready excitability of the auditory nerve without any modification of the normal formula. Indeed it is often astonishing to witness the ease with which the auditory reacts in such cases; with currents that are almost imperceptible and hardly affect the needle of the galvanometer the complete formula of the auditory reactions can be obtained. Even when the electrode, if negative, is placed in the subclavicular fossa or on the neck, patients of this class are known to complain spontaneously and of their own accord of noises in the ear. It is by such cases that the existence, precision, and regularity of the galvanic auditory reaction can be made clear to the most obtuse and brought home to the most sceptical.

Thus an increased power of reaction even with a very weak current is the first and most striking evidence of this galvanic hyperæsthesia. This is evinced not merely by the early occurrence of sensations with the KC, but also by the fact that the AO sensation is produced by comparatively feeble currents and close upon the KCS.

Later it is found that the sensations of sound become very loud and intense and very marked in timbre and character (loud blowing, groaning, roaring, ticking, &c.) Further, these sensations of sound are remarkably protracted; they are of much longer duration than usual, so that very soon the KC sound comes to last during the entire period of closure in the circuit, although with a somewhat decreasing intensity (and hence the KD reaction ∞ = infinite duration); and in like manner the AO reaction, usually momentary, becomes changed into a loud noise which lasts for some time (20 to 40 seconds) and slowly dies away.

The formula for simple auditory hyperæsthesia, as it is obtained with much weaker currents than in the normal nerve (with 12, 8, or 4 elements as against 16 normal), is expressed in order thus:—

KCN'' . .	very loud noises in the ear
$KDN\infty$ . .	noises lasting as long as the current remains closed
KO . . .	nil
AC . . .	nil
AD . . .	nil
$AOn' >$ . .	brisk noises, gradually dying away

Brenner has further shown that in this condition of hyperæsthesia the secondary and tertiary excitability is essentially increased, and that this increase is shown even in the response to simple positive and negative changes, as well as in several other respects.

As a higher degree of hyperæsthesia must be reckoned what Brenner has described under the name of the 'paradoxical reaction.'[1] This may be briefly said to be characterised by the fact that when only one ear is armed and explored and the other electrode is placed in the hand, on the sternum, or elsewhere in a fixed position, the other ear reacts at the same time and in the same way with reference to the indifferent electrode, as if it were armed with the latter. This is regarded as paradoxical only because Brenner has found that the reaction of the ear or auditory nerve is in all cases determined by the nearest electrode. We should expect, therefore, in the case alluded to that the unarmed ear should also be influenced in its reaction by the electrode with which the other ear is armed, since that is much nearer to it than the one held in the hand or placed on the sternum. Now this is not so: quite the contrary. But it may easily be shown, as I have stated in its proper place, that with the mode of exploration described all the currents entering the skull by one ear must leave it through the neck; whether the electrode B be placed behind the latter, in the hand, or on the sternum, or on one of the legs, it matters not (fig. 25); and in every case the effect is the same as if the indifferent electrode were applied to a transverse section of the neck. But in every case too the unarmed ear is nearer to the transverse section of the neck than to that to which the electrode is applied. Its reaction is therefore determined by the indifferent electrode acting from the neck. Seen in this way the phenomenon is no longer a paradox. It is merely the expression of a degree of excitability so high that even the feeble shocks which reach the unarmed ear are sufficient to produce in it the sensation of sound. It would be better, perhaps, to abandon altogether the term 'paradoxical

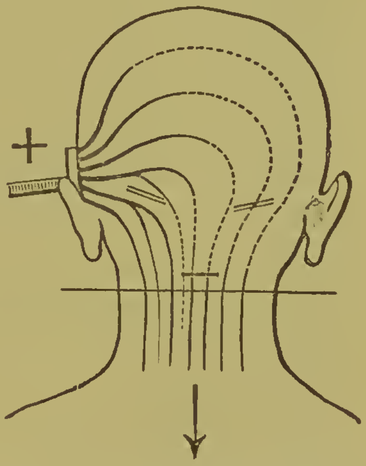

FIG. 25.—Diagram to show the distribution of the current through the head, when one ear is armed with the anode. The virtual K is represented at the transverse section of the neck.

reaction.' In order to show how the thing occurs I supply the following case of *bilateral hyperæsthesia of the auditories*:—

(*Note.*—Electrode A to left ear; electrode B in the hand.)

	Armed Ear.	Unarmed Ear.
8 cells:	KCN″	—
	KDN∞	—
	KO	n >
	AC	N
	AD	N∞
	AOn >	—

The sensations of sound, therefore, alternate in the two ears, and it is possible by using one or other pole to produce them in either at will, with opening or closure. This occurs with mathematical constancy, and more than anything else can be made to demonstrate the most striking effects.

But if this increased excitability is present in one side only, while the other ear is healthy, it may happen that the regular formula of hyperæsthesia is derived from the affected part, and at the same time if the sound ear is armed and examined it remains unaffected by a certain strength of current, but the paradoxical sounds are produced in the hyperæsthetic one, opposite. Thus it is a remarkable fact that the unarmed ear reacts, while that to which the electrode is applied fails to do so. I have recorded many such instances.

When the paradoxical reaction is present, if both ears are examined at once with the same (divided) electrode they both react with full energy.

This simple galvanic hyperæsthesia of the auditory is certainly of common occurrence. I have often found it accidentally in people who are hardly conscious of any abnormal condition. It may be manifested by moderate disturbance of hearing accompanying slight but appreciable changes in the ear, as thickening and retraction of the membrana tympani, partial atrophy of that structure, &c.; and it is very common in long-standing ear diseases of every kind—e.g. prolonged suppuration, purulent inflammation of the middle ear, perforated tympanum, chronic catarrh of the middle ear accompanied with difficulty of hearing and noises, also in caries of the petrous portion of the temporal bone, in consequence of gunshot wounds and other lesions, in fractures of the skull, in rheumatic and traumatic facial paralysis, &c.

Brenner further lays stress upon the very frequent co-existence of this and other morbid reactions in the auditory nerve with central and intracranial disorders, involving paralysis of the optic mechanism, and his statement is supported by Hagen and myself as the result of observation of a number of cases, amongst them paralysis of the ocular muscle, mydriasis, paresis of accomodation, &c., following upon fractures of the skull and intracranial disease of various kinds. It is undoubtedly in many instances a mere coincidence; but there is often too a causal relation between the two states and they are seen to depend equally upon the same central changes.

Galvanic hyperæsthesia (and other anomalies) of the auditory are in fact occasionally met with in *central diseases*—affections of the brain and spinal cord, tabes, chronic myelitis and encephalitis, cerebro-spinal meningitis, tumours, &c. The exact connection between these disorders and the central lesion has not yet been sufficiently established. It may be that the central disease directly affects the galvanic excitability of the auditory, in such a manner as is often to be seen in connection with motor nerves, e.g. in tetanus and tabes. Again, it is conceivable that, as in neuroretinitis and papillitis, trophic derangements take place in the auditory as a consequence of the central disease and give rise to the anomalous reactions. Lastly, it is possible that the hyperæsthesia of the auditory is secondary to disease of the middle ear, itself produced in this way. All these conjectures, however, demand closer consideration. Very interesting too is the galvanic hyperæsthesia of the auditory, with or without qualitative modifications of the formula, which Jolly has often demonstrated in the cases of hallucinations of hearing.

Brenner has suggested a very ingenious way of accounting for galvanic hyperæsthesia in ear disease. It is founded upon the well-known fact that the nerves of special sense, when long deprived of their appropriate stimulus, are thrown into a state of intense excitability or 'craving.' Hence it is that we learn to distinguish surrounding objects gradually when we have been some time in the dark, and are dazzled by the day-light when we come out; hence too we see the luminous effects of electricity better in the dark than in open day. So it is with the auditory nerve. If in consequence of disease of the conducting structures the usual stimuli reach it with difficulty or not at all, it falls into this condition of 'craving' for excitation, which is displayed by a readier reaction to galvanism. If this state of things lasts for some time, other changes (nutritive derangement) may take place in the auditory, and these are manifested by a reaction which is at once excessive and perverted, and which may end in the total loss of excitability in the nerve. This view would also explain the anomalies of galvanic reaction in the auditory, which will be spoken of later. But, however attractive, the explanation holds only for those cases in which galvanic hyperæsthesia is coexistent with ear trouble involving the mechanism of hearing. True such cases are the majority, but there are certainly others in which there is no trace of functional derangement that yet display galvanic hyperæsthesia of the auditory. Amongst the latter are those which exhibit in addition deviations from the normal formula. I have seen many such, and I have taken upon them the opinion of aural surgeons. For these, then, we must find some other way of accounting for the presence of galvanic hyperæsthesia. Now there is nothing to prevent our supposing that the errors of nutrition which underlie the condition of hyperæsthesia, and which we meet with so often in other parts of the nervous system, may here affect the auditory primarily and through other channels. It remains, it is true, to determine what these channels are.

Simple hyperæsthesia occurring in connection with subjective noises in the ears is constantly met with, and the condition has been accorded great practical importance. It is a source of intense discomfort, and it often resists every effort that the specialists have devoted to its cure. Its origin is not generally understood, but Brenner has treated the subject with his usual skill and perspicuity. I shall have occasion to revert to this in the part of this work that deals with therapeutics. For the present it is sufficient to say that these subjective noises are sometimes produced within the nerve itself. In a large number of such cases there is present a simple hyperæsthesia of the auditory, and they are further recognised by the fact that the electrical current has a controlling effect upon the noises in the ears. It is usually found that the subjective sound ceases at once and entirely with the passage of the AC or AD shock, while the AO causes it to return with as great or even greater severity than before. The KC and KD greatly aggravate the noises, and KO induces only a momentary cessation. It very often happens too that they are diminished but not completely dissipated by the AC shock, and this is best seen by reversing the current from K to A. Finally, Brenner has observed cases in which the noises were relieved by KC, KD, and AO—that is, by the same excitants that cause acoustic sensations.

In another class of these subjective noises we must look for their cause altogether outside the nerve. They are entirely unaffected by the galvanic current, whatever its force and direction.

And there is a third group intermediate between these two, in which noises of different kinds are present together, so that one is amenable to the controlling influence of the current, while the other persists in spite of it. Here again there is hyperæsthesia, as a rule, although it may not be of a pure form. The former of these noises probably proceeds from the nerves.

It will be seen from this that in the galvanic exploration of the mechanism of hearing, by the determination of galvanic hyperæsthesia of the auditory on the one hand, and of the soothing or exciting effects of the various galvanic stimuli upon the noises in the ears on the other, we have at our disposal an important criterion to help in forming an opinion of the nervous condition underlying certain forms of this troublesome disease, and so discriminating them from others.

As a further development of simple hyperæsthesia, but of less common occurrence, must be mentioned—

(*b*) *Galvanic Hyperæsthesia with Anomaly or even Conversion of the Formula.*

Here to the normal sensations of sound are added other pathological sensations—first usually the AC and AD sensations, later that of the KO—always associated with the characteristic symptoms of hyperæsthesia. The morbid sounds experienced almost invariably differ, in character and timbre, from those produced from normal excitants, and they are quite as constant in their relation to one another as the normal sensations in healthy persons, or the KC and AO sensations in simple hyperæsthesia.

Let us take in illustration the following case, from a man of 54, suffering from partial deafness, old-standing noises in the ears, thickening and retraction of the tympanum:—

Left ear: External method of examination; B on the hand:—

10 cells:	KCWh′ .	. loud shrill whistling
	KDWh∞.	. prolonged whistling
	KO : h .	. short humming noise
	AC : H′ .	. loud buzzing and humming
	ADH > .	. gradually fading
	AOWh > .	. whistling as in KC

The sounds may be of a very different nature in different cases—whistling, ringing, resonant, humming, groaning, buzzing, &c.—but in all the KC and AO and KO and AC give rise to sensations that are similar to each other and differ from the rest.

But it is also observed that these new morbid sensations become gradually more intense and grow louder and clearer. Further, they arise earlier and more easily than the sensations caused by the normal excitants, which on their part become less and weaker and constantly more difficult to produce. Finally, it may happen that the normal sensations are entirely lost, leaving only the morbid ones, with a constantly increasing excitability. There is then said to be *hyperæsthesia with complete conversion of the normal formula.* The following, from my notes, will serve as an example.

A lady, aged 60. *Right side*, simple hyperæsthesia; *left*, hyperæsthesia with conversion of formula. Deafness partial in right ear, complete in left. Noises especially in left ear. Old disease; formerly much otorrhœa; considerable thickening and retraction of the tympanum on both sides.

External method of exploration ; B on the hand :—

	Right Ear.		Left Ear.
4 cells :	KCWh′	6 cells :	KC –
	KDWh∞		KD –
	KO –		KOwh >
	AC –		ACWh
	AD –		ADWh∞
	AOWh >		AO –

Thus in the left ear the formula was absolutely the converse of the normal, while the hyperæsthesia was somewhat less than that in the right. In the left the subjective noises were dissipated by the KC shock, but remained unaffected by AC.

I would have you remark here the obvious analogy that exists between the development of the modifications of galvanic excitability of muscle in the reaction of degeneration, and the course of these anomalous processes in the auditory.

The various degrees of hyperæsthesia, from the simple form to complete conversion of the formula, may be expressed in the following table of abbreviations (after Hagen) :—[1]

KC :	Kl″	Kl′	Kl′	Kl	kl	—
KD :	Kl∞	Kl∞	Kl∞	Kl >	kl >	—
KO :	—	—	s	s	s′	s >
AC :	—	S	S′	S′	S′	S″
AD :	—	s >	S >	S∞	S∞	S∞
AO :	kl >	kl >	kl′	kl	—	—

It is unnecessary to say that you will not be able in each individual case to follow the entire course of the development of this condition, or to determine its stage at a given time. Still a large number of observations have shown that in a selection of cases at all events the course of the modifications was that represented here.

These forms of hyperæsthesia, with modifications and conversion of the formula, are to be met with, it would seem, only in old ear disease, extensive destruction of the middle ear, disease in the labyrinth, &c. It is for aural surgeons to determine the precise connection between these and the different anomalies of galvanic reaction.

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[1] In this table it has been thought advisable to retain the original symbols, so as to prevent the misconception that might arise from translation. Kl stands for 'klingen,' ringing ; S for 'sausen' or 'zischen,' singing or buzzing, which finally may become more intense and pass into ringing or whistling.—TRANSLATOR.

But in such cases it may happen that the hyperæsthesia grows less and disappears, and there remain only the anomalies of the formula. We then speak of—

(c) *Qualitative Anomalies of the Galvanic Reaction of the Auditory without Hyperæsthesia.*

Under this term are included anomalies of every kind that are not accompanied by increased excitability of the auditory, and of these Brenner, Eulenburg, and others have furnished many examples. Any conceivable variation may occur from the normal reaction with all six excitants to complete conversion of the formula. We may have such and such a morbid reaction present, or a particular normal one absent, so that there is the utmost variety in the formulæ produced, as will be evident without the need of further illustration.

But it by no means follows from the presence of these anomalies that they were preceded by a simple hyperæsthesia. In a particular case this is not even probable. On the contrary, the result of a series of observations, which included rheumatic paralyses of the face, central affections, injuries to the skull, &c., went to show that the auditory may be directly influenced by a perverted and deranged nutrition, so as to react abnormally without any other change. Finally, I must not omit to mention that qualitative modifications of the formula may arise from structural changes in the parts that are in relation externally with the auditory nerve, of such a kind that the paths of the current, or the virtual poles, approach it in another manner and by different channels from the normal.

These modifications are met with usually in inveterate ear disease, of many years' standing and considerable severity; but they have also been observed very frequently in rheumatic facial paralyses and central disorders.

Since man has two ears and these are not always affected in the same way, it follows that the galvanic reaction of the auditory may be of a different form in either. Whether the affection is unilateral or bilateral, this may differ in nature, intensity, and duration. If, therefore, there is considerable hyperæsthesia, so that the 'paradoxical reaction' is displayed, it may happen that a certain method of exploration discovers a deplorable confusion and inconstancy in the sensations of sound, especially if in one or both ears there are qualitative modifications or conversion of the formula. An experienced physician has no difficulty in interpreting these phenomena. He will readily form his opinion from a strict and careful examination—studying each ear separately as far as possible, employing a divided electrode, and resorting for the purpose to every available expedient. True there are many cases in which it is not possible to establish complete regularity, and this is especially so where the patients are ignorant and unobserving, and with an intelligence further impaired by extreme deafness. But we must not make use of such persons for the study of scientific truths, and still less should we rely upon their statements to criticise and impugn other facts that are well ascertained and based upon sufficient authority.

In conclusion I ought to add that there are grounds for assuming a condition of diminished excitability or

(*d*) *Torpor of the Auditory Nerve.*

When it is present currents of considerable strength are needed to excite the nerve, and with these we can get only feeble KC sensations, or perhaps none at all. Here of course we must eliminate any unusual obstruction to the current, excessive resistance to conduction, &c. You are aware, gentlemen, that even under ordinary circumstances galvanic excitation of the auditory often fails of effect. Hence it behoves us to hesitate before we assume such a torpor in the nerve. The diagnosis is most easily established in cases of unilateral disease, or where it is possible to follow directly the gradual transition from a ready but abnormal excitability to one that is morbid and obtuse, as it has happened to me in one instance.

Torpor of the auditory is met with for the most part only in severe and incurable disorders of the sense of hearing, in which the precise connection between the functional derangement and coexisting anatomical changes is not quite clear. The latter are not necessarily commensurate with the trouble. The condition, however, is uncommon and difficult to recognise.

3. With reference to *galvanic excitation of the Nerves of Taste*, the only pathological condition known as yet is a simple diminution or loss of the galvanic sensation of taste. This may be readily demonstrated by the methods pointed out above. But as yet no qualitative anomaly has been discovered. The question arises whether in peripheral paralyses of the nerves of taste we shall ever be able, by central excitation of the peripheral nerves themselves, or by stimulating the central organs in relation with them, or at least their connections within the brain, to produce sensations of taste, and in this way determine the peripheral character of the lesion by means of electrical exploration. I think this is doubtful, but it is certainly conceivable. At all events we can hope to solve the problem only by means of cases that are peculiarly favourable.

The idea of an electrical diagnosis of the *nerves of smell* as of the *vasomotor and secretory nerves*, *the sympathetic of the neck*, *the pneumogastric*, *the cardiac muscle*, *the bladder*, *the uterus*, *and the central organs of the nervous system*, is at the present day no longer entertained. The statements published upon the subject are without practical value. The observations of Hitzig, however, on *the reaction of paralysed muscles in blood vessels* are in every respect deserving of mention. This writer found, in many cases of paralysis of the axillary nerve, that, in the region of cutaneous anæsthesia produced, excitation with strong and labile galvanic currents induced marked pallor of the skin, at the same time that the neighbouring healthy parts assumed a purple tint. On the other hand more prolonged excitation, with a strong and stable galvanic current, or the faradic brush fixed on one spot, caused a more or less marked dilatation of the vessels. Hitzig inferred from this the existence of vaso-dilator nerves, which had previously not been sufficiently established; and he ascribes the effects produced to excitation of the muscular fibres alone, their nervous supply being cut off. In these cases they are said to have exhibited an increased amplitude of contraction, but only slight power of dilatation. Hitzig has also seen similar but equally obscure manifestations in other nutritive and paralytic disorders. The subject, however, still remains open to investigation.

The communications of M. Rosenthal upon cerebral galvanic torpor seem to me to need further support and elucidation.

FIFTH SECTION.

GENERAL ELECTROTHERAPEUTICS.

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LECTURE XIII.

Therapeutical Value of Electricity—Various Theories concerning It—Empiricism—Available Effects of the Current: Catalytic, Exciting, Modifying, Refreshing—Direct and Indirect Catalysis—Galvanisation of the Sympathetic—Reflex Action of the Current.

GENTLEMEN, we now come to consider the therapeutical action of electricity, what is its value and what are its limits in various morbid states. We may start with the assertion that it is a remedy both very powerful and varied. It has yielded such evident results, especially in the treatment of the nervous disorders, as to occupy a very high rank as a means of cure. The experience of the last thirty years goes to show that electricity can cure neuralgias, anæsthesias, spasms, paralyses, and certain other diseases of the peripheral as well as of the central nervous system. Many disorders have a much more favourable prognosis since its introduction into our therapeutics. I am not exaggerating when I say that the cures so obtained very often astonish the most experienced physician by their completeness and rapidity. It is true that such marvellous cures are not of everyday occurrence, but certain it is that they do happen now and then; and they are a powerful incentive to the efforts of the physician in his slow and toilsome advance in therapeutical science. On the other hand we cannot conceal from ourselves the fact that our theoretical knowledge of the way in which these phenomena are produced is still very deficient. The curative processes of electrisation are still withheld from our understanding, and we cannot tell how far they are connected with those physiological effects of the current with which we are acquainted. Many attempts have been made to clear up the mystery; every electrotherapeutist, tempted by the progress of physiology, consciously or unconsciously conceives some idea about the therapeutic action of electricity. There is no wonder therefore that during the early days of this special branch of medicine its devotees should have prematurely built up a system upon theoretical data. We have all had our share therein; but we scarcely need deplore those 'days of youth' which have been the occasion of more than one solid piece of work towards the elucidation of the main problem, which still waits for its solution.

The cause of our ignorance is, I think, to be found mainly in the obscurity which still reigns over the nature of the finer alterations, nutritive or molecular, present in the nerves in various morbid conditions. We know but little concerning the precise character and the ultimate causes of the inflammatory troubles which are constantly evolved before our eyes, of the degenerations and atrophies which have been the subject of numberless experimental researches. How much more obscure, then, must be the nature of the disturbances which are at the root of neuralgias, spasms, paralyses, and other neurotic phenomena! We are often ignorant even whether a pathological increase of function is due to over-excitation or over-excitability; whether a paralysis depends upon non-excitability or upon non-conductibility, or upon inhibition. We cannot help, however, holding certain provisional views concerning all these topics; and it is well that we should do so, but it must not prevent our making constant efforts to expand our interpretations with every advance of scientific knowledge.

The data we possess concerning the action of electricity on the body are far less numerous and precise than appeared to be the case during the first enthusiasm for electrophysiological discoveries from 1850 to 1860. We know with exactness only the phenomena connected with the excitation and modification of the nervous and muscular irritability. We know practically nothing of the electrolytic and cataphoric actions of electricity on the body. With reference to the 'catalytic' influences of which we have to speak so often, we must confess that they are purely hypothetical, and that this expression is merely a collective name, including several effects of the individual nature of which we are still ignorant. Who can affirm that there are not other influences exerted by the current upon the human body, such as alterations in the molecular nutrition, in the production of heat, in the elementary affinity, in the osmotic phenomena, &c., on which the chief therapeutic phenomena depend?

Among the various electrotherapeutical systems which have hitherto had most partisans the chief is the *electrotonic* theory. It is of purely physiological origin, and seeks to explain all the facts by the modifying effects of the current on nervous excitability. What seems more natural than to seek a cure for neuralgias in the anelectrotonic or 'calming' effect of the positive pole, whilst paralyses are submitted to the catelectrotonic or 'exciting' influence of the negative pole? But we are not at all sure that there is always in the one case increase, in the other diminution of the excitability; moreover the electrotonic effects are but transitory, whilst the curative results are often durable. Again, as R. Remak observed, it is less the excitability of the nerve than its conductivity which is the main point to be attended to. We may also object that it is almost impossible to excite in the body a single polar influence, as we have seen before, because the effect of the other pole is always present. It is true that it has been asserted that the positive modification after anelectrotonus can be avoided, and that certain results of the electrotherapeutics of the auditory nerve, obtained by an application of the polar method, are very striking. Yet such views and facts are scarcely sufficient to furnish a basis upon which to establish a wide generalisation.

These difficulties produced a return to the old primitive theory that electricity cures by the *excitation* of the tissues. But this view does not lead us far, and is not justified simply because the electrotonic theory is untenable, and because the exciting effects of electricity on the nerves are the only ones as yet well known to us. Besides it is impossible to understand how this one influence of the current can explain the curative results obtained by its means in many different forms of organic disease and functional disturbance. We shall see later on that we may thus explain some of our results, but certainly not all. As far as I can see there is only one possibility, a very hypothetical one, on which we might explain the fact by the existing effects of the current—I mean a stimulation of the trophic nerves, the existence of which, though not proved anatomically, can hardly be doubted. It is probable that every nerve contains trophic fibres and is placed under the influence of trophic centres, upon which the electric stimulus may act, and so modify the nutrition of nerves, muscles, and other organs, hastening regeneration and removing the more subtle nutritive disturbances. We may assume that gymnastic and other methodical exercises influence the muscles by an excitation of the nutritive processes due to the calling into play of the trophic nerves under the stimulus of motor activity. Is it not possible in the same way to account for many of the curative results of electrisation by assuming a stimulation of the trophic processes?

We are treading here upon the ground of another theory which has been again put forward of late, rather for want of something else than for any intrinsic merit of its own: I allude to that which is based upon the *catalytic* action of the current. Here it is sought to analyse the curative influences and reduce them to this very trophic action, along with effects on the vasomotor nerves and vessels, and the osmotic, electrolytic, and mechanical properties of the current. We have already seen (Lect. VII., p. 129) that this notion of catalysis involves many obscure points concealed under a collective term. It may serve rather as a provisional hypothesis to lead us to ulterior investigations than as an explanation of the facts. R. Remak, who first invented it, displayed much insight into the general problem of electrotherapeutics, without, however, contributing greatly to its final solution.

We are therefore compelled to admit the defective foundation upon which depend our knowledge and resources in electrotherapeutics at the present day. No less than formerly it all rests upon empiricism, and much has yet to be done before it is established upon a firmer basis.

In our efforts to this end we must make use of the facts discovered by physiology, and the hypotheses resulting from them. They will furnish us with information in the choice of our methods, and show us the proper way to set about interpreting and controlling their results. But it should never be forgotten that experience must be the final arbiter, and that the inferences drawn from a system that is based upon physiological grounds alone are not necessarily correct, but need to be supported, as far as possible, by observation and experiment in morbid states.

After these general considerations, I propose to enumerate the different current agencies that are available in therapeutics, according to what we have seen in our previous discussion, and to lay before you briefly the objects for which each is used and the way in which it is applied.

The *exciting and stimulant* action of the current is the most commonly resorted to, as it is capable of the most varied use and the finest graduation. It is called for under widely different circumstances, in peripheral and sometimes too in central diseases, and especially wherever we may hope to remove the morbid condition by vigorous excitation, as when we seek to obviate resistance to conduction in sensory or motor nerves, or, by frequent stimulation—or, so to speak, exercise—to restore impaired excitability, and re-establish the partly suspended conductivity of the fibres. It is further used to stimulate the trophic nerves and promote nutrition, directly or indirectly, by exciting contractions to favour the development of atrophied muscles; or, again, where it is desirable to replace the suspended activity of muscles by a kind of electrical gymnastics. Finally, it is indicated when we wish to exercise an exciting or modifying influence by reflex action on the central organs, and through them on distal parts of any kind—on the vasomotor nerves and muscles, the organs of respiration, circulation, &c.

The methods to be employed for these several purposes are easily deduced from what I have already said.

The *faradic current* is applied with moistened electrodes of suitable shape and size when the object is to excite subcutaneous parts or structures still more remote; with dry electrodes, on the other hand—and preferably the metallic brush or pencil

—when we wish to excite vigorously the nerves or other tissues of the skin. The latter method is especially useful to induce reflex stimulation.

In the use of the *galvanic current* we have at our disposal a still larger variety of methods. The simplest excitant is that of *negative closures*, which may be repeated with increasing force and frequency. Less effective are the *positive opening and closure*, but they also may be resorted to on occasion. An excellent method of causing excitation is the *labile* application of the current, first employed by R. Remak, and especially the labile application of the negative pole. It is performed in this way: The negative electrode being well moistened, it is rapidly and energetically applied with a rubbing movement in the course of the nerve trunk or muscle to be excited, and a current is employed of sufficient strength to cause vigorous undulatory contractions. For this purpose it is usually sufficient to make use of such a current as would produce ordinary KCC in the same nerve. The powerful exciting properties of this method of treatment certainly do not proceed from variations in the current strength, for the galvanometer shows no movements in the needle even while the most energetic contractions are produced. It is rather due to the fact that the movement of the electrode brings fresh portions of the tissue constantly within the line of greatest current density, and these are consequently excited. This method is admirably adapted to the purpose of exciting nerves and muscles with moderate force, so as to produce the most favourable results. The positive pole may be similarly employed, but it is less efficient. In a high development of the RD, however, it will cause the most vigorous contractions. Remak has described under the name of 'terminal labile excitation' a friction with the K of the parts of long muscles that are in the neighbourhood of their tendons, at the same time that the muscle is similarly treated throughout its entire length. This proceeding is very effective, especially in some of the long muscles of the extremities.

Finally, the most powerful excitation is derived from rapid reversals of the current, especially by changing it to K when the A has been some time in action. The frequent repetition of these reversals, or, as they are called, 'voltaic alternatives,' is sometimes the only means by which contraction can be procured in muscles that are extensively atrophied and of much impaired excitability. Hence they are chiefly relied upon in cases of long-standing paralysis and extensive atrophy.

A further extension of this mode of electrical action is derived from the combination of the excitant and stimulating effects of the galvanic and faradic currents, both being simultaneously applied to the parts under treatment. This is the method of *galvano-faradisation*, introduced by de Watteville. The secondary coil of the induction apparatus is connected with the galvanic circuit (by means of the contrivance described on p. 41) in such a way that the opening current of the former has the same direction as the galvanic current. In this way the exciting influence of the faradic current is made to supplement the modifying action of the galvanic, by working most where this is wanting; and by adding to the exciting effect of the galvanic K the excitability-promoting properties of faradic K stimulation a much greater efficiency is secured with a given current strength, as is evident at a glance.

The double electrodes which Stein has constructed for the same purpose, and by which the two currents, having an independent course, first meet within the body, seem to me to be superfluous. No doubt they would be useful in physiological experiments, since by their means the currents can be opposed in direction.

The place to be chosen for the application of these different methods of excitation obviously depends altogether upon the seat and nature of the disease, and to a less extent upon the object which it is proposed immediately to effect. I will merely mention here that when the object is to overcome resistance to conduction in the course of the nervous impulses, the excitation of sensory nerves should proceed from the periphery, of motor nerves as much as possible from the centre. In nerves and muscles that are undergoing degeneration and atrophy it is important that the excitation be applied directly; and to obtain reflex actions it is necessary to choose in all cases the sensory regions that are most suitably situated.

In the next place we often wish to make use of the current for its *modifying* properties—its power of influencing the condition of excitability. There is no doubt that in many instances theoretical conditions would induce us to expect much benefit from this source. Such are all cases in which there is evident loss of excitability in nerves and muscles, in many paralyses and anæsthesias, certain vasomotor disturbances, states of impaired activity of the brain and spinal cord. For these the *catelectrotonic action* (stimulating, strengthening, antiparalytic, refreshing) of the current may be invoked with advantage. Wherever, on the other hand, we have to do with an increased excitability of nerves and muscles, an irritable condition of sensory, motor, or vasomotor nerves, abnormal excitement of sensory organs, even if it be in the central nervous system—as, for instance, neuralgias, spasms, spinal irritation, headache, insomnia, auditory hyperæsthesia, hemicrania, &c.—the *anelectrotonic* (which according to circumstances may also be termed weakening, sedative, soothing, antineuralgic, antispasmodic) action of the current is especially indicated.

The methods by which these effects are secured are very simple. They are, undoubtedly, less to be relied upon when the faradic current is used, for we know little of its modifying properties. It is usually assumed that weak faradic currents lead to an increase of excitability, while those that are very strong and energetic, we are told, lessen that quality. This has been inferred especially from observations in pathology and therapeutics; but I would call your attention to what I have already said. Even though it were certain that neuralgia or spasm was often removed by the use of very strong faradic currents, it does not follow that it was a consequence of diminishing excitability; for that has yet to be shown.

To induce a diminution of excitability the 'fluctuating' induction current, first employed by Frommhold, is often used with success, and is effected in the following way: Large stationary electrodes well moistened are placed on the part and a weak current passed through them. Then the coils are slowly drawn together, and the current strength increased until the greatest that is thought desirable is attained. At this point they are allowed to rest for a little while, and then gradually separated. This process may be repeated several times in the course of a sitting.

Galvanism, however, is a more reliable source of these modifying influences. Here I need only remind you of what I have said, in its proper place, concerning electrotonus. If you desire to *increase excitability* you have only to apply the negative pole in a stabile manner and with currents of increasing strength and duration, so as to do so to any extent. Even the opening of the current is followed by a considerable alteration of the excitability, which persists for some time. If, on the other hand, your object is to bring about a *decrease of excitability*, the stabile application of the anode is the appropriate means to be adopted. Here too the effect is in proportion to the strength and duration of the current. But here arises a fresh and a great difficulty. With the opening of the current after the cessation of the anelectrotonus, there is straightway produced, as you know, a considerable positive modification, or increase of excitability, which renders the result of the entire proceeding questionable. This must be avoided somehow, and it may be obviated securely and effectively enough for practical purposes by what is called 'switching off' the current. This is done by diminishing its strength with great care, gradually and imperceptibly, by means of the collector, the switch or a good rheostat, until zero is reached. That this procedure, when skilfully conducted, is followed by the desired result, is proved conclusively by many cases of auditory hyperæsthesia, for even with a greatly exalted excitability we can in this way entirely evade the anodic closure reaction, and dissipate the subjective noises, for a shorter or longer period. I shall have occasion later to give a more detailed account of special modifications of these methods in connection with different forms of disease.

Amongst the modifying effects of electricity is undoubtedly to be included what Heidenhain long since described as the *refreshing action* of the galvanic current. It is derived best from stabile and ascending currents; but it probably depends for the most part upon the electrotonic effect of the negative pole, and it has its most appropriate application in debility and exhaustion of the motor apparatus, consequent upon fatigue, excess, and such like causes.

However obscure the precise nature of the *catalytic effects* of the current, there is no difference of opinion as to their existence and remarkable efficiency. I have already dwelt upon this subject at some length (Lect. VII., p. 129), and I have here but to repeat what the name has been understood to include since it was first used by R. Remak. By the catalytic action of the current is meant its effects upon the vasomotor nerves—and these perhaps should be distinguished as vasoconstrictor and vasodilator—upon the blood vessels, and possibly too upon the lymphatics and the lymph itself; upon the phenomena of osmosis and molecular distribution, the interchange and movement of the solid and liquid constituents of the tissues. It is electrolytic and cataphoric, and is perhaps the source of hypothetical changes in the trophic nerves. In fine, and as resulting from all this, it may be taken as the expression of the current's influence upon the phenomena of absorption and nutrition in general. We have here an abundance of potentialities, which should lead us to hope great things from electricity in the most various pathological states not only of the nervous system, but of the body, in whatever part. In inflammatory disturbances of all kinds, whether acute or chronic (neuritis, myelitis, sclerosis, &c.), in processes of exudation of every description, in rheumatic affections of the joints, muscles, or nerves, in extravasations, in all the phenomena of degeneration, in the numerous errors of nutrition, more or less tangible or obscure—in all alike it has its application. It is hardly possible to conceive of any kind of disorder in which we may not hope to derive benefit from its influence.

Though it is impossible to deny the existence of this mode of action, we are far from being able to bring about its effects at will, and we are not yet even in a position to recognise the cases in which it may be resorted to with a prospect of success.

In a previous lecture (p. 130) I placed before you in a collective form the physiological data which may be regarded as the foundation of our knowledge of these catalytic effects, or at all events as the point of departure for further investigations. I will here mention some pathological and clinical observations which seem to point out the reality and practical importance of these effects, and further offer some sort of basis for wider researches in this interesting field of study.

I will direct your attention in the first instance to the results of galvanic treatment in the different forms of *neuritis*. R. Remak has himself reported many cases of primary and secondary neuritis in the brachial plexus and nerve trunks elsewhere, and also of neuritis nodosa, in which the pain and swelling disappeared more or less promptly with the use of galvanism. Mor. Meyer has seen a median neuritis, with perceptible swelling, vanish before the use of stabile anodic currents. He has lately published a similar observation in connection with traumatic and other forms of neuritis. F. R. Fischer has described an undoubted case of median neuritis from my hospital in which pain and swelling vanished under the same treatment; and I have been since able to establish a like satisfactory result in many cases. On the other hand the case reported by Althaus is not conclusive.

The observations in different forms of *arthritis* are still more numerous. Remak has published an abundance of remarkable cures in acute and chronic joint affections of rheumatic and traumatic origin, which leave no doubt of the antiphlogistic action of the galvanic current. Amongst others he reports one of hydarthrosis of the knee, with extensive inflammation, and another of chronic coxalgia. M. Rosenthal has seen many chronic articular exudations absorbed under galvanism. Mor. Meyer tells of many cases in which faradisation or galvanisation was employed with success. In arthritis vera Cahen has adopted a rational treatment with the rotatory apparatus and obtained a good result. Proceeding similarly with galvanism, Chéron was equally successful in a case of rheum. art. deformans. Weisflog obtained unequivocal results with local faradisation in traumatic and scrofulous inflammation of the knee, and he has pronounced it absolutely 'the best, most infallible, and most valuable antiphlogistic remedy in traumatic joint affections.' E. Remak has employed the galvanic current with success in monoarticular rheumatism. I can myself speak highly of its effects in articular exudations. Benedikt also relates in his work an entire series of observations in which he met with like success. Onimus and Legros report a very favourable case of this kind. Erdmann has met with brilliant success in treating a serious case of multiple and chronic joint disease with faradism and galvanism.

Further, there are many instances of the *resolution* and *partial absorption of glandular tumours* by electricity. Remak has induced resolution of hard and swollen lymphatic glands by means of the galvanic current (possibly through dilatation of the lymphatics). He has also in this way reduced a glandular enlargement of strumous origin. Mor. Meyer, by the use of strong and often interrupted faradic currents, has succeeded in removing or diminishing multiple indurated lymphatic tumours; and Chvostek has treated in several instances strumous glands, many of long standing, with stabile galvanic currents, and has often reduced them with wonderful rapidity, sometimes completely. So too he has seen indolent bubos absorbed rapidly in the same way; and Seeger claims to have been equally successful in inflammatory glandular swellings. Onimus and Legros give similar instances of cure in connection with glandular tumours. One of these is remarkable in that it involved two symmetrical tumours, of which one was treated with the positive and the other with the negative pole. The former was the first cured.

Not less remarkable are the effects of galvanism as seen in *hard cicatrices, rigid joints,* and *periostoses* in consequence of gunshot wounds. Mor. Meyer has seen deep cicatrices in muscles soften and disappear, and periostoses from gunshot injuries absorbed with remarkable rapidity. Both effects were procured by the use of the positive pole. Chéron, again, has seen stiffness of the joints and plastic exudation from gunshot wounds removed, chiefly, by the application of the kathode.

Finally, we are in possession of facts bearing upon the obvious effects of electricity in *contusions, extravasations, subluxations,* and *inflammations.* Remak has met with brilliant success in a sprain of the wrist, swelling and stiffness disappearing immediately. He has had a similar experience in a serious case of sprained ankle. He was equally successful in chronic cases of the same kind, and has cured the rigidity and thickening consequent upon articular inflammations by means of the current. So too Chvostek, by labile galvanisation of the nerves, contrived to remove a chronic inflammatory infiltration of traumatic origin in the leg. Sycianko claims to have repeatedly cured acute inflammation of the gums by treatment with the positive pole; and Chéron and Moreau-Wolf maintain that they have had great success with galvanism in the treatment of blennorrhagic and traumatic orchitis, and chronic hypertrophy of the prostate.

We have here a sufficient number of examples. It would be easy to enumerate others, but these are enough to show that in different organs superficially placed the electric current has effected a palpable and obvious cure of serious structural lesions. It cannot be doubted that it would be possible to obtain similar results in parts more deeply placed. We should be led too far from the immediate purpose of this discussion were we to consider all the instances recorded in which obvious disease of the spinal cord or brain was cured by electricity, in a way that can only be ascribed to its catalytic action.

That these effects are produced there can be no manner of doubt, however little we know of their essential character and *modus operandi.* It remains to make many observations, conscientiously and unbiassed by preconceptions, before we can arrive at a final solution of this problem, which is perhaps the keystone of electrical therapeutics.

The catalytic action belongs especially to the galvanic current. This, which is *à priori* probable from what we know of the nature of the currents, is sufficiently established by practical experience. The greater number of the results of this kind hitherto published have been derived by means of galvanism, and no doubt it is precisely in this respect that it has the advantage over faradisation, especially in the treatment of remote organs. But that the faradic current has also had remarkable success is sufficiently evident from the cases which I have quoted.

The best way to obtain the catalytic effects of the galvanic current is by stabile electrisation of the affected part with a sufficiently strong and persistent current. It is well to change the direction frequently—that is to say, to alter the poles—because by this means the vasomotor, electrolytic, and cataphoric effects are undoubtedly increased. The position in which the electrodes are to be placed depends of course on the situation, size, and accessibility of the affected part. Where we have to deal with a small neuritic patch we may cover it entirely with one electrode, while we place the other in some indifferent situation. For a diseased joint or a pain in the head the two electrodes are so disposed as to include between them the seat of the disorder; for in this way the latter is submitted to the most direct and intense electrisation possible. In other cases other modes of application will be necessary; but these must always be contrived so that the affected part shall be reached with the greatest certainty attainable, and by currents of appropriate density.

At this point you will naturally enquire whether each pole has not its own function, and whether one is not to be preferred in one case and the other in another. On *à priori* grounds, indeed, this seems very likely, but as yet we are not in possession of sufficient evidence to affirm it definitely.

It is generally thought that wherever electricity is used to check undue excitability, exuberant processes, abundant accumulation of fluid, excessive infiltration, or severe pain, the positive pole should be applied to the part by preference. The kathode, on the other hand, is said to be indicated for chronic conditions, where the processes are sluggish and protracted, for diminished vascularity and excessive dryness of tissues, for indurations, scleroses, and the like. There is no conclusive testimony in favour of these views, but in commencing treatment it is as well in all cases to be guided by them. Many facts point to the conclusion that it is rather the opposition of the two that is effective, or at all events that it is a question not so much of the specific action of the poles as of direct electrisation; and for this reason it is my habit to place both poles upon the affected part, and often change the direction of the current, or where I employ a single pole I use first one and then the other.

Chvostek assumes, on theoretical grounds, that only currents of short duration (in all 3 to 10 min.) and moderate strength are needed. He maintains that the catalytic effects depend chiefly upon stimulation of the vasomotor and trophic nerves. At the same time he believes that it is better to treat the affected part directly, and not merely by excitation of the nerves supplying it, so as to secure the electrolytic and cataphoric action of the current as well.

In addition to treatment of the affected part, it seems in many cases useful to employ a stabile and labile application to the neighbouring structures—vessels, lymphatics, muscles, and skin—so as indirectly to promote the circulation, absorption, and nutrition in those that are diseased. Frequent interruptions and even reversals may serve to render the current more effective than otherwise, for relaxing spasm and promoting the nutrition of atrophied muscles, &c. This plan may be adopted also with evident benefit in the treatment of diseased joints.

The *faradic current* is less active in producing catalytic effects. Its mode of application is simply to pass 'fluctuating' currents of varying strength as directly as possible through the affected part, as, for instance, a diseased joint. For the resolution of glandular enlargements M. Meyer's plan was to pass the strongest currents, by means of moistened electrodes, for some minutes, effecting frequent interruptions. In this way the tumours were broken up and gradually reduced in size.

R. Remak has introduced a process of *indirect catalysis.* It is said to consist of a modification of the circulation and nutrition of the tissues in consequence of galvanisation of the nerve trunks supplying them. Remak maintains that, by galvanising in this way nervous structures remote from the focus of disease, he has been able to bring about the absorption of extravasations, the reduction of articular swellings, the development of atrophied muscles, &c. He considers it especially efficacious for the easing of pain in inflamed structures, as joints and the like, to apply the anode in a stabile fashion to the nerve trunk as far as possible from the seat of disease. There is no reason to doubt this statement when we reflect that by acting upon the vasomotor fibres in the nerve we can certainly influence the circulation of the remote parts which it supplies. Still it is eminently desirable that these independent observations should be confirmed by others, so as to place the theory of indirect catalysis upon a surer basis. Chvostek has published some very important experiences in connection with this subject. He has seen a chronic œdema of both legs, the result of a wound, rapidly removed in consequence of labile galvanisation of the tibial and peroneal nerves, and he maintains that he has observed a pannus of the cornea with acute conjunctivitis almost entirely disappear before prolonged galvanisation of the sympathetic. Indeed this question has derived considerable and undue importance from a number of statements and hypotheses connected with *galvanisation of the cervical sympathetic*, as a therapeutical procedure. R. Remak himself, and later Benedikt, as well as M. Meyer, Beard and Rockwell, &c., maintained that in this way it was possible to control the vasomotor and nutritive processes of the brain and spinal cord, of the face and eye, the muscles, joints, even the skin, and all parts of the body, and that consequently we might expect great benefit from it in morbid states, where the disease was inaccessible to direct treatment. As a matter of fact many cures are said to have been effected by this method in certain cerebral hemiplegias, trigeminal neuralgia, migraine, paralyses and spasms of the facial and ocular muscles, bulbar paralysis, neuro-retinitis and optic atrophy, Basedow's disease, epilepsy, progressive muscular atrophy, lead palsy, arthritis deformans, scleroderma, and various skin diseases (eczema, prurigo, &c.) Should all these observations prove to be accurate by the light of further experience we should certainly have in this procedure one of our most valuable resources. Some of them are certainly beyond dispute, but it does not follow that the results obtained are to be entirely ascribed to the cervical sympathetic; for in the usual methods of galvanisation of this nerve, to which I shall allude presently, the sympathetic is never alone affected, but a considerable part of the current is undoubtedly diverted to the pneumogastric, carotid, the nerves at the base of the skull and the brain itself, the cervical and brachial plexuses, and above all to the cervical part of the spinal cord and medulla oblongata with its numerous and important centres that preside over the blood vessels, the pupils, respiration, the heart, the nutrition of muscles and joints, &c. The question arises whether these parts are not of greater consequence than the sympathetic.

I am not disposed to attach much importance to the fact that the numerous physiological experiments on the cervical sympathetic in healthy persons, of which I have already spoken (p. 112), have failed to indicate any practical advantage in this proceeding. This proves absolutely nothing, and it is an infatuation that is unfortunately as common as it is unscientific to attempt to deduce definite conclusions with reference to morbid states and phenomena from negative results derived from healthy nerves. What information have we gained from the numerous physiological experiments upon the sensory and motor nerves as to the possibility of curing a spasm or neuralgia by electricity and the way in which this may be done? Or, to take a more striking example, have the electrical experiments of physiologists furnished us with the darkest hint for galvanisation of the cord? Is the clinical success which has attended the treatment of the spinal cord less assured because, under ordinary circumstances, we cannot produce the slightest effect upon that structure with the current? Or, again, to take an analogous instance from another quarter, has the physiological investigation of bromide of potassium provided us with a reason for using that remedy in epilepsy? Has physiology taught us enough of the properties of arsenic to show us how it is that it works its cures in chorea minor and tic douloureux?

In such matters experience alone can provide a rule for practice. The negative results of physiological research cannot, in the face of clinical facts, prevent us ultimately from resorting to what is called galvanisation of the sympathetic, and accepting it on its merits as a process of therapeutics. They do but render it more imperative to be circumspect in the interpreting of these facts, and place us on our guard against attributing to the sympathetic, without sufficient reason, qualities which, perhaps, it does not possess. On these grounds I willingly accede to the proposal which has been made to substitute provisionally for the misleading term 'galvanisation of the cervical sympathetic' that of 'galvanisation of the neck,' although the latter less definitely indicates the position of the electrodes. Perhaps it would be better to call it 'subaural galvanisation,' as de Watteville proposes.

The best method is certainly that of Mor. Meyer. One pole (medium electrode) is placed at the angle of the jaw, against the hyoid bone, and with its surface directed backwards and upwards towards the vertebral column. The other pole, which is a little larger (large electrode), is applied to the opposite side of the neck, on a level with the 5th–7th cervical vertebræ. As a rule the kathode is chosen for the first-mentioned situation, in the neighbourhood of the superior cervical ganglion; the anode, however, may be applied here when occasion requires. Moderately strong currents (6 to 10 Stöhrer's cells; 2 to 5 ma.) are usually sufficient, and they are generally stabile. Labile currents, however, are sometimes required, and it may be necessary to interrupt, or even reverse. The application, as a rule, should not last longer than 1 to 3 minutes; and it may be made at one or both sides, according to the circumstances of the case.

Benedikt has preferred another method. He places the positive electrode, shaped like a button, in the jugular fossa, the negative over the superior ganglion. For anatomical and physical reasons this plan is less practical than the other. Moreover it withholds the powerful influence of the current on the spinal cord, and this is not desirable. The course to be adopted in treating other parts of the sympathetic—the lower cervical, thoracic, and abdominal ganglions—will be suggested in each case by anatomical considerations.

I may call your attention here to certain *reflex actions* of electric currents, which are also catalytic, inasmuch as they affect the contraction and dilatation of vessels—I mean the changes induced in the vessels of the brain and cord by faradisation of the skin and peripheral nerve trunks. These phenomena have lately attracted much attention, and they are well worth investigation, because, if the facts which have been recorded are ultimately confirmed, they will find a practical application in disease. Contraction and dilatation of the vessels of the pia mater in the brain and cord have been observed—although not constantly—by many authorities to follow excitation of the nerves and peripheral organs (Callenfels, Nothnagel, Brown-Séquard, &c.) Nothnagel in particular has found that contraction of the cerebral vessels is caused by excitation of the skin and, less constantly, by that of the afferent nerves. These facts have lately been confirmed by Rumpf in the course of some experiments on vascular reflexes in states of defective sensibility, and he has found that vigorous and prolonged faradisation of the skin caused transient anæmia, followed by congestion in the opposite hemisphere. He suggests that the changes so induced in the vessels of the central organs may be utilised in disease for curative purposes. Perhaps we may explain in this way certain effects produced in the central organs by peripheral electrisation, and of which we shall speak in the Special Part of this work. Rumpf himself has lately described some cases in which peripheral faradisation of the skin seemed to exercise a favourable influence on central hyperæmias, optic neuritis, tabes dorsalis, &c. For this purpose he applied the faradic pencil slowly and with some pressure to the breast, arms, and back, using a current of moderate strength and for a period of 5 or 6 minutes. These statements at all events demand further elucidation.

You will have inferred from what I have said that the theories which guide us in the use of electricity, as a mode of treatment in disease, are very defective and inadequate. The great expectations which were encouraged by the rapid accumulation of facts have not been realised. We are still confronted by a number of problems towards the solution of which we have not yet made any progress. Our most important task is still the development of electrical therapeutics upon empirical principles.

We are inspired, however, with great confidence by the brilliant and undoubted successes which have been achieved in practice. Every day adds to their number and compels us to acknowledge with gratitude the benefit derived from this powerful remedy, especially in the treatment of those nervous diseases whose name is legion. We can also console ourselves in our disappointment by the reflection that in other branches of therapeutics we are no less ignorant of the nature of the the most vaunted measures. What do we know of the way in which quinine cures intermittent fever, or salicylic acid relieves acute articular rheumatism; of the action of arsenic in skin diseases, or of iodide of potassium in tertiary syphilis? And yet it would be folly to allow our ignorance of the way in which these things are done to spoil our satisfaction at the wonderful cures effected. So it is with electrotherapeutics. The number and magnitude of the results which it has already furnished should provide us with a motive for renewed exertion in the investigation of its mysteries, as they afford a hope that these will be ultimately crowned with success.

LECTURE XIV.

The Methods of applying Electricity in Local Diseases—The Polar Method and the Method of Direction—Advantages of the Polar Method—Empirical Methods—Effects on the Organism as a whole of (1) General Faradisation (according to Beard and Rockwell); (2) General Galvanisation; (3) Central Galvanisation (Beard); (4) The Electric Bath—Special Modes of Application: (1) Galvanic Treatment of Points of Pressure and Pain; (2) Treatment by Means of Weak Continuous Galvanic Currents.

We shall now leave the more general and theoretical considerations with which we have just been occupied, and devote our attention in this lecture to others of a concrete and practical nature. And first we have to consider how and by what means, with reference to the choice of electrodes—their size, disposition, situation relatively to the parts under treatment, and the like—we may best and most securely bring about the desired remedial effects of electricity.

From what I have already said you must have recognised the fact that we can hardly hope to establish our procedure upon *à priori* principles, such as would afford a warrant of success. We must rather trust to experience for our method, or at all events it must be confirmed and controlled by empirical knowledge.

Certain hypothetical views and obscure notions of physical facts have given rise to an animated discussion, which has hardly yet concluded, as to whether the separate polar action or the direction of the current should be adopted as the general principle of our methods. The latter—that of the so called 'method of direction'—was first advocated by R. Remak, under the pressure of the physiological theories by which it was the fashion to explain the entire law of contractions, and the phenomena of electrotonus as determined essentially by the current direction. It is true that Remak has since recognised the importance of the polar actions, but he has endeavoured to explain them by regarding the action of the A as of a descending and that of the K as of an ascending current. Their nature and utility then seemed to him to depend upon the direction of the current, whereas in fact the converse is true. Benedikt likewise, reasoning in a very loose way, has proceeded upon this principle as a foundation for therapeutical measures, and deduced from it the appropriate position for the electrodes. And many others have followed the example of these two.

To them was opposed Brenner with his well-founded and carefully considered 'polar method,' according to which the action of the separate poles, and in consequence the appropriate application of one or the other to the affected part in every instance, was the important factor in any plan of treatment.

Neither of these theories has been exclusively adopted, and this fact, together with the most casual consideration of the subject, will show that there are many questions in electro-therapeutics which were not at issue in the controversy. What, for instance, has the direction of the current to do with the treatment of glandular tumours, goitre, inflamed joints, &c.? It is only in acting upon the nervous system that the point can be raised at all.

For us, however, the question is of much interest, and it behoves us to weigh the reasons for and against either method, so as to form a careful judgment that may guide us in our further proceedings.

As to the *direction of the current*, we know, to begin with, that for the most part it is impossible to send an effective current in a given direction through a nerve in the living body; that we have rather to reckon with at least three possible directions of the current in each operation; and further, as I have shown you at some length, that these currents constantly and rapidly diminish in density (vide p. 75). The only conceivable condition under which a definite direction can be imparted to the current, at least in separate nerve sections, is that in which it is passed from one extremity (hand or foot) to a more central part of the limb or to the trunk. Moreover this holds only for the distal portions of the nerve. Careful consideration will make it clear that portions of the current are necessarily diverted in every direction from the neighbourhood of the central electrode, having themselves a centripetal course, especially when the electrode is on the trunk. Further, this method can find its application only in a very limited number of cases. The advocates of the method of current direction therefore must begin by contriving other modes of application than those that have been hitherto in use, in order to produce, in a given case, a current that is confined to one direction. Until this is done the evidence they allege in support of their views is exposed to an obvious fallacy. Another and the most important objection is that as a matter of fact we have no reason whatever to suppose that in general the action of the current is determined by its direction. On the contrary physiological investigation has shown conclusively that all its effects with which we are as yet acquainted — exciting, modifying, electrolytic, &c.—are without exception due to polar action, and are manifested alike, whatever the direction, provided it be not exactly transverse. In fact, the direction of the current does not seem to have any material influence in the production of these polar actions. It is only in certain determinate cases (Pflüger's third law of contractions) that the *conduction* of an excitation (which, however, is *originated*) is obstructed in one direction or another, and with the utmost goodwill it is impossible to construe this as an effect due to direction; for the arrest of conduction occurs equally for the ascending and descending currents, in sensory as in motor nerves, and can be referred to certain polar effects (obstruction of conductivity).

From this it would seem that there are no grounds for adopting current direction as the fundamental principle of our methods. At any rate there is no scientific necessity for accepting such a principle, while considerations of practical utility, and in some cases, too, others of a speculative nature, may induce us at times to employ a method based upon it.

On the other hand we must weigh against it the great advantages of the *polar method*, and the arguments in its favour, depending as they do upon physiological and physical laws, no less than upon facts of clinical experience.

In the first place physiological analysis has shown that the effects of the currents, so far as we are at present acquainted with them, and can apply and control them in disease, are exclusively due to polar action, and are associated in each case with one or other pole. Indeed, it is a rule that every effect of the current is most pronounced in the immediate neighbourhood of the poles.

In the next place it is a good deal easier in practice, and a much more reliable proceeding, to place certain parts of the body—muscles, nerves, &c.—under the most intense attainable action of one or other pole, than to attempt to pass a current in a particular direction, with a uniform intensity, all through. This purpose can be effected surely and with ease by attending to anatomical and physical conditions, and using discretion in the choice of the electrodes. Here, indeed, we are met by a serious objection. It is impossible, as we have seen, to secure the exclusive action of one pole upon a given part of the body. The other must necessarily exert its influence at the same time. But if you reflect more closely upon the way in which the currents become split up and the inconsiderable density and activity of each part in most cases, it will not be difficult to perceive that the action of the *different pole* must greatly preponderate, so much so that that of the secondary pole may usually be neglected. Moreover there are means by which the latter can be rendered still more inconsiderable at the same time that the action of the primary (different) pole is intensified in the nerve sections upon which it is brought to bear.

It was for these reasons that we adopted the polar method for electrical exploration in diagnosis on the living subject when those matters engaged our attention, and we are no less compelled to acknowledge them now as a basis for practical therapeutics.

In addition to this there are abundant clinical facts which go to prove the efficiency of the polar method and the justice of the views upon which it is founded. The most striking are those that have reference to noises in the ears—auditory hyperæsthesia, &c. (Brenner, Hagen, Erb, &c.) In such cases as a rule the pole whose use is indicated by the galvanic formula is very efficacious in arresting the noises and diminishing hyperæsthesia, while the other is without effect or perhaps even injurious. In conformity with the principles of the polar method Holst has devised a plan of galvanic treatment for migraine, and it has realised his expectations.[1] O. Berger ascribes very brilliant successes in the treatment of facial neuralgia to the use of a strictly polar method (stabile action of the positive pole). Althaus has resorted to a similar procedure in painful affections of the teeth. In other forms of neuralgia too the polar method has given admirable results, and here mention may be made especially of the 'circle currents' introduced by Remak. The treatment of painful pressure points, which has been so much studied of late (R. Remak, Mor. Meyer, Brenner), is chiefly effected in strict conformity with the polar method.

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[1] I am at a loss to understand the process of reasoning by which C. W. Müller has arrived at a conclusion unfavourable to the polar method, from the consideration of the two cases of migraine communicated by him (l.c. Obs. 1,

We have here, therefore, important materials gathered from every quarter, and together they form a body of evidence in favour of the advantage of the polar method in therapeutics.

But the most decisive consideration is that which results from the reflection that our principal object, in every form of electrical treatment, is to submit the affected part in the most certain and effective manner to the action of a current of sufficient density, avoiding at the same time the secondary and injurious effects of the process. To attain this end by the light of a sound diagnosis, and trusting mainly to the agency of precise physical laws, is undoubtedly the first and most important condition of our method. And it is this, I take it, that constitutes skill in the physician.

Since, unfortunately, we are ignorant, in most cases, of the manner in which the electric current acts we are concerned to take care that it *does* act, or at least that it is in a way to do so. To this end, and seeing that we have to work directly upon small and separate parts of the organism, it is clear that we must employ the polar method, because it is the most practicable and that which secures the greatest measure of success. For parts of greater extent—large nerve trunks, the spinal cord, &c.—the different electrode may be moved from place to place throughout the entire extent of the affected organs ; but this has nothing to do with the so called labile treatment : the secondary electrode may then be placed upon some indifferent part, such

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2). It remains to show that the two cases were identical; and in estimating the polar effects upon the vasomotor system, the strength, density, and duration of the current are undoubtedly of the utmost consequence. For the rest, it is evident that Müller employs the word 'polar' in the same sense that I do.

as convenience may suggest or definite physical considerations induce us to choose. It may also, as E. Remak judiciously observes, be used simultaneously as a second different electrode, as, for instance, in the treatment of painful points, to act upon the *locus morbi* itself.

But in the last resort experience must be our guide as to whether one pole in particular—and, if so, which—is the more efficient. It is in only a very limited number of cases that this can be predicted with tolerable certainty on *à priori* grounds. Now, in some instances, as for auditory hyperæsthesia, certain neuralgias, migraine, painful pressure points, &c., the verdict of experience has been already given; but there are many others in which it has not yet spoken. Of course we may and should avail ourselves, in empirical investigation, of the information that is to be derived from the facts and principles of physiology; but the utmost circumspection is called for in the interpretation of phenomena, and our inferences should be controlled with the most rigorous care. Neither should we be astonished if here and there we meet with something that fails to harmonise with our views. In not a few instances you will see both poles exhibit a similar or identical action—in many conditions they do but quantitatively differ—and especially with reference to catalytic effects we have been unable as yet to assign the preference to one or the other, or to determine their respective functions.

From all that has been said it seems probable that the direction of the current has no considerable influence from a therapeutical point of view. But this has still to be proved. Here again the final appeal must rest with experience, and experience, for the purpose, must be based on a sufficient observation of various instances. At any rate it may be expedient in some cases to impart a particular direction to the current, so as to secure or intensify the action of one or other pole. But this too is only an extension of the polar method.

You see, then, gentlemen, that in reality we have to deal only with empirical methods. You cannot be too much upon your guard against the preconceived illusions of theory. There are others that spring from clinical prejudices and ill-observed facts. The literature of electrical therapeutics unfortunately abounds with misconceptions of this kind, and it is not singular in this, for the fault is common to nearly all the special branches of the science. Wherever the critical faculty and a rigorous control of inferences are wanting such errors are sure to arise, and anyone who knows the difficulty of collecting a body of positive and incontrovertible clinical facts will readily pardon the defect.

The remarks that have been hitherto made have reference essentially to the local treatment of local diseases. We have yet to consider some other methods that have for their object the production of a more general influence upon the entire organism. These methods have been contrived for the treatment of certain forms of disease in which there is a general derangement of the entire nervous system—as in various forms of neurasthenia, hysteria, hypochondriasis, &c.—or states of constitutional debility consequent upon some disorder of the blood or of nutrition—as anæmia, chlorosis with nervous derangement, muscular relaxation, &c.—or, finally, certain conditions in which it is sought, by means of electrical excitation of the entire body and especially of the nervous system, to effect a cure of morbid tendencies of a circumscribed or extended character, as in general debility, hysteria, extensive vasomotor weakness, diffuse skin affections, multiple joint disease, and the like. There can be no doubt that these methods are often productive of great benefit. I shall describe them here, so as to avoid making the Special Part of the course too long.

1. *General faradisation* was first advocated by Beard and Rockwell, and practised by them extensively. Its object is faradic excitation, as considerable as possible, of the entire organism, but affecting especially the nervous system, the muscles, and the skin. The method which they adopted is as follows:—

The patient is first stripped or lightly clothed in a shirt, or a jacket, and trousers. He is then made to lie upon a couch and the bare feet are placed in contact with a very large electrode, covered in the usual manner and well soaked (or they may be placed in a vessel filled with warm water), and connected with the K of the secondary coil. The A is made by the physician's hand, well moistened, his other hand holding the electrode, so as to make the current pass through his own body, as was Beard and Rockwell's practice almost exclusively at first; or, better, it may consist of a large electrode carrying a sponge cap of 5 to 8 cent. diameter (fig. 26),[1] with which different parts of the body are successively brought in contact.

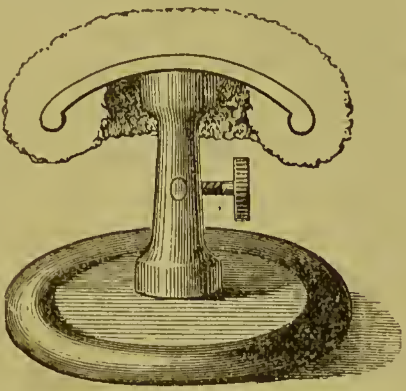

FIG. 26.—Large round sponge electrode, with a short handle used in general faradisation. Transverse section. Half natural size. The electrode carries a thick cap of sponge.

The 'electric hand' may be used preferably in sensitive people for application to the forehead and front of the neck, for it enables the physician to exercise complete control over the strength of the current, and further because the great adaptability of the hand renders the process a very gentle one. The treatment begins with the forehead and temples, and an appreciable current is passed through them. The top of the head is reached next, and here the A is allowed to rest for some time. Then the occiput and nape of the neck are treated with a somewhat stronger current, and again increasing the current, the electrode is passed for some time along the spine, so as to stimulate the cord. It may be allowed to dwell occasionally at certain parts, over a painful spinal apophysis or focus of disease. The physician now proceeds to faradise the neck with a weaker current, in order to excite the sympathetic, the pneumogastric, the phrenic, and the cervical muscles; the anterior region of the thorax, especially of the heart, and the abdomen with stronger currents. At this point the A may be applied for a time to the epigastrium, so as to act upon the cœliac plexus. It should afterwards be passed slowly over the entire surface of the abdomen, for the benefit of the viscera and abdominal muscles. Then follows vigorous excitation of the skin and the muscles of the back and extremities, and for this purpose the electrode is applied with suitable pressure to various parts and especially to the larger nerve trunks and the muscles. Each of these should be submitted several times to the excitant action of the current, and its strength should be regulated to the production of energetic contractions. The sitting may terminate with a second and shorter excitation of the spinal cord. The entire proceeding should occupy 10 to 20 minutes; and of course the intensity, duration, and minor details of the treatment will vary greatly for different individuals and the several forms of disease.

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[1] This electrode may be fixed in an ordinary handle; but when it is necessary to apply it beneath the clothing—as in treating women—it may be attached to a short button-shaped handle, that can be grasped firmly in the hand, and of which an idea may be had from fig. 26.

Beard and Rockwell claim for their method the following advantages: The immediate effect is generally refreshing and tonic; pain and lassitude instantly disappear; the pulse beats more regularly. But in sensitive persons it may also cause vertigo, malaise, tremulous movements, and fainting; and in the first few days following the treatment other ill effects may become apparent, as muscular pains, nervous excitement, aggravation of certain symptoms, headache, and sleeplessness. The more permanent results with which it is credited are many and various. Sleep is improved, appetite increased, the digestive processes repaired, circulation promoted, the body advanced in weight, muscular tone, and development throughout; pain is relieved and morbid susceptibility overcome, uneasy sensations in the head removed, nervousness and mental depression corrected; and in fact a general restoration of the mental and physical faculties is effected. Beard and Rockwell attribute these results partly to direct excitation of the nervous system, partly to the repeated and powerful contractions induced in the process. As an indication for the employment of their method they mention especially 'constitutional affections.' To be more explicit, general faradisation is called for in morbid states that are characterised by a general impairment of the nutritive and vital functions, as neurasthenia, hysteria, hypochondria, and nervous dyspepsia, anæmia, chlorosis, paralysis, constitutional neuralgia, and certain derangements of the genital and digestive organs; also for pathological symptoms of obscure causation, as in many cases of neuralgia and paralysis, epilepsy and hysteria; finally, in diseases which, themselves incurable, are attended with impaired nutrition and other symptoms—as insomnia, nervousness, and general debility—which we may hope to relieve. General faradisation has not yet found many advocates, but the communications which have been published by others (Väter von Artens, P. J. Möbius, Engelhorn, Fr. Fischer) confirm the statements of the American writers. We are told of satisfactory and even brilliant results in cases of cerebral and spinal neurasthenia, chlorosis, general nervous exhaustion of the insane, &c. For myself, although my experience in this direction is limited, I have employed general faradisation often enough to convince myself that it is frequently of great utility. The complicated and tedious nature of the process, however, is a considerable obstacle to its use.

2. *General galvanisation* is altogether analogous to the last process, except that it is effected by means of the galvanic current. Here, again, the negative pole is applied to the feet, and the positive is directed over the patient's body in precisely the same manner as that described above. The effects are the same, according to Beard and Rockwell. More care, however, is needed with reference to the nervous organs, and the A being applied to the muscles the contractions will probably be less considerable than those derived from faradisation. The two American writers have employed this method only as a secondary resource. For my own part, I have little experience of it.

3. On the other hand, Beard has devised another expedient for utilising the galvanic current. He calls it *central galvanisation* (Väter von Artens would prefer the term *pancentral*) and he claims for it great advantages. It is effected by placing upon the epigastrium a larger negative plate-electrode, while the positive pole in the form of a sponge electrode, also of large size, is applied to the head, the sympathetics, and the spinal column throughout its entire extent. Its object is to act upon the central nervous system, the vagus, and the sympathetic. With a weak current (2 to 8 cells) the forehead is first gently rubbed from one side to the other, then the skull and the vertex midway between the ears—a point to which Beard attributes great importance—and the application is continued here from 1 to 2 minutes. Then the A is passed for 1 to 5 minutes along

the course of the cervical sympathetics and the pneumogastrics. Finally, the spinal column is rubbed slowly for 6 minutes along its entire length, attention being devoted especially to the upper part.

This process may be compared to general faradisation, but it especially affects the central nervous system. It may be employed in neuroses of various kinds, especially those in which general nutrition and muscular tone are still comparatively unimpaired. For these latter functions general faradisation is especially efficacious. But the two methods may be combined and used alternately with great advantage. Beard maintains that he has seen central galvanisation work most brilliant cures in hysteria, hypochondria, chorea, cerebral and spinal neurasthenia, gastralgia, nervous dyspepsia, &c. He also relates instances of its salutary influence upon skin diseases (chronic eczema, prurigo, acne). For my own part I have adopted the procedure in a few instances, but without marked success. But I cannot regard my failure as conclusive evidence, and I still look for satisfactory results from further experience. Those mentioned by Beard are sufficiently remarkable to encourage the hope that a more extended acquaintance with their nature will throw much light upon some subjects of theoretical importance.

4. I have yet to say a few words on the subject of another method of general electrisation of the body. It is one that has been proposed and described under various forms, but it has not yet been accorded universal support. I refer to the *electric bath.* Electric baths may be contrived in many ways, and of all of them very wonderful things are told. One method of administering the bath is as follows: One pole is connected with the tub in which the patient is placed, if this is of metal, or passed into the water if the vessel is of some non-conducting substance—as of wood—while the other is attached to a metal bar covered with some conducting material and well moistened. This is suspended above the vessel, and the patient grasps it with his hands. Care must be taken that the surface of the body is nowhere in contact with the metal of the vessel or with the pole that has been introduced within it. This may be effected by placing a stool under the patient or clothing him in a light costume. In this way the patient's arms become the channels

by which the current enters and emerges from his body—that is to say, they are one of the poles of the galvanic or faradic current. The other consists of the entire surface that is in contact with the water. This is called the 'monopolar electric bath,' and according as one or the other pole is connected with the water, and therefore with the surface of the body, it may be termed the anodic or kathodic (monopolar) bath. Under the conditions described the current may cause so great uneasiness in the arm that a point is soon reached at which its strength and intensity cannot be increased without discomfort. The second pole may then be applied at some convenient situation on that part of the body which is uncovered, as the nape or spine, or it may be conveyed to a point beneath the surface of the water by means of an insulated electrode (rubber electrode of Trautwein).

In another form of the electric bath the vessel is made of some non-conducting substance—wood, concrete, or thoroughly enamelled metal—and by various contrivances the electrodes of the primary or secondary faradic coils, or of the galvanic apparatus, are introduced into the water it contains. In this way the body receives only so much of the current as belongs to it by the laws of Ohm, and this is regulated as to direction and density by the relative position (fixed or changing) of the poles. The different parts of the body may be submitted to the more or less active energy of the current by approximating or removing them from the electrodes. If it is desirable to pass very strong currents large electrodes may be used, one towards the head and one towards the feet. These should consist of metal plates of large surface and suitably curved, carrying the attachment of the terminal wires of the battery. The current strength may be further increased by adding to the water some substance that will render it a better conductor, such as common salt, soda, or a little acid.

This is called the *dipolar electric bath*, because neither of the poles is applied directly to the patient's body, but all the currents must pass through the water to reach it. They may be conveyed to the water either by plates at the head and foot only (and Stein would add a perpendicular plate between the legs, connected with the foot plate), or others may be situated at the sides, so as to impart an oblique or transverse direction; and either pair may be connected with the poles of the battery by means of suitable commutators. The ingenuity of the specialist and instrument-maker has produced these in great variety, but only the simpler forms are of practical utility.

To generate the current a powerful induction coil, or a battery of many cells and low resistance, is needed. Arrangements for admitting and shutting off the current, for increasing, diminishing, and estimating its strength and reversing its direction—in fact, all the appliances of complete electrisation—are indispensable for administering the bath. For the purposes of private practice, however, the faradic bath may be given in its simplest form without much trouble. The best medium is pure water. By reason of the great resistance of the fluid, even with the bipolar method, a sufficient quantity of electricity enters the body to produce the desired therapeutical and physiological effects. Saline or acidulated water, which has a much lower resistance, increases the strength of the current, but allows a smaller share to enter the body, although, to be sure, it would seem, from Lehr's experiments with the water of the Wiesbaden springs, that its effect in this respect is not very considerable. On the other hand, in giving the monopolar bath it is well to increase the conductivity of the fluid by adding a little salt, soda, or acid.

The temperature of the electric bath can be regulated according to the general indications of the case. As a rule it is taken tepid—32° to 37° C. The strength of the current too will be chosen with reference to existing conditions. As a rule it will be of such a strength as to be just appreciable to the skin, but it is well to fall short of this point at the outset and afterwards gradually to increase the strength.

The duration of the bath varies from 10 to 30 minutes, according to circumstances. Where the object is merely to refresh and stimulate the nervous system, short baths and weaker currents are sufficient; to diminish nervous excitability they should be continued longer and stronger currents used.

Local electric baths have also been employed (Weisflog). In these one electrode is replaced by a dish containing water, into which the affected part is plunged. So too in the general electric bath a more local action can be produced in the separate parts by attaching one pole to Stein's 'shovel electrode' and bringing it in close proximity with the structures to be acted upon.

We cannot, on *à priori* grounds, altogether reject the idea that the electric bath may be possessed of remarkable powers. It is the procedure that has the best claim, as Schweig justly remarks, to the name of 'general' electrisation, since by its means the entire body, with the exception of the head, is submitted simultaneously to the influence of the current. It is only quite recently that the physical and physiological conditions which must form the basis of subsequent clinical investigations in this matter have attracted the attention of several observers (Stein, Eulenburg, Lehr, Spanke, Graeber, Trautwein). As yet these preliminary questions are far from being settled. The obscurity of the underlying physical laws and the contradictory nature of the results of physiological research render it incumbent upon us, I think, to be very reserved in forming an opinion upon the action and efficacy of the electric bath.

As to the *physical conditions*, it needed no showing that in the monopolar bath the entire current entered the patient's body; not so with the dipolar. Eulenburg, in his discussion of this subject, indulges in certain somewhat unscientific hypotheses, but states that he has failed to find, by direct experiment, that any considerable quantity of the current entered the body. The same conclusions seemed warranted by Lehr's investigations—inevitable from those of Trautwein. Yet surely the fact has been long since sufficiently established by the manifest physiological effects of the dipolar bath. The resistance of the body appears to be somewhat less than that of pure water, greater than that of the hot springs; and it will receive, in the dipolar bath, as much of the current as will fall to its share by Ohm's laws of distribution. The nearer its surface to the electrodes—where the density is greatest—and the shorter the column of water which the current must traverse to reach it, the greater will be the quantity it receives.

From a physiological point of view it has been shown that muscular contractions and even the electrotonic effects of the current can be produced in the electric bath (Lehr); that in the faradic and galvanic baths faradic and galvanic excitability are respectively increased by currents of moderate strength, diminished by those of greater force and longer duration (Eulenburg, Lehr). The electrica sensation is produced early in the skin, and especially in those parts where the current is most dense. Farado-cutaneous sensibility is diminished, at any rate by faradic baths, particularly when of long continuance. With reference to the galvanic bath the conclusions of Lehr and Eulenburg are contradictory and leave the point in doubt. The sense of *position*, according to Eulenburg, is exalted by the bath, of whatever form (faradic and galvanic, anodic and kathodic). According to Lehr it is first exalted and then depressed in the faradic, while in the galvanic bath the K induces exaltation and the A depression of that faculty. Spanke has ascertained, and Graeber confirms, the same facts in connection with the sense of *touch*.

The conclusions of the various observers are unanimous in showing that the *pulse rate* is considerably diminished (8 to 20 beats per minute) in both the galvanic and faradic baths (Eulenburg, Lehr, Schleicher, V. Corval, Wunderlich). *Respiration* is diminished (3 to 6) in the dipolar, little (1 to 2) or not at all in the monopolar bath. The *temperature* is lowered by the latter 0·1° to 0·7° C. *Metabolism* is promoted considerably by the dipolar, slightly by the monopolar bath (Lehr); and there is increased secretion of urine. *Appetite* and *digestion* are improved. The genital functions are stimulated. Circulation and nutrition are benefited, sleep notably restored, and new vigour imparted to the mental and physical faculties. In short, the electric and especially the faradic bath is credited by all those writers with a powerful *invigorating* and *refreshing* action upon the human frame.

The result of these researches is not such as to afford sufficient grounds upon which to formulate therapeutical indications for the use of the electric bath. To regard it, with Eulenburg, as merely a cutaneous stimulant in the same category with other baths of this class—hot water, carbonic acid, and mineral baths—would certainly be to limit its action unduly. It is undoubtedly an adequate means of general faradisation and galvanisation, and it is reasonable to suppose that it may be possessed of the various alterative and other qualities which are attributed to those processes. Clinical experience is alone competent to settle the matter, and a large body of facts are needed to establish the indications for its use and for that of one form preferably to another. There is even now an abundance of such material to help us at all events in determining the effects of the electric bath in a large class of cases, even though we must suspend our judgment as to the comparative advantages of the different ways of administering it.

There can be no doubt as to its efficacy in states of debility and impaired nutrition, and especially in the various functional neuroses—e.g. neurasthenia of any kind, and particularly sexual neurasthenia, nervous dyspepsia, palpitation, hysteria, hypochondria, Basedow's disease, &c. Further, it is beneficial in tremulous states (mercurial and alcoholic tremor, &c.) and even in paralysis agitans, where it will effect at any rate a decided alleviation of symptoms. It has also been known to do good in the spasms and rigidity of hemiplegia and spastic spinal paralysis (Lehr). For all these conditions the faradic bath appears to be especially suitable. Its effects are but little marked in neuralgic and parasthenic states, though in these too they are not altogether wanting; and much may yet be achieved by the use of the appropriate form and method (monopolar galvanic bath). In muscular rheumatism and old and chronic forms of articular rheumatism it has been given with great advantage (Bouillon-Lagrange, Barth, Schweig, Lehr). Even in gout it is said to be a palliative of great value (Lehr), and Weisflog has derived much benefit from long-continued local faradic baths in traumatic and other forms of inflammation in joints. The electric bath is also said to be of use in alleviating the pains incidental to breaking off the habit of morphinism. All these things, however, are in need of further confirmation.

As to the comparative merits of the monopolar and dipolar methods, we must look for information to further researches. In my judgment the dipolar bath is more convenient, easier of application, and suitable for the greatest number of cases. In most instances too it will be advisable for the present to content oneself with the simpler and more manageable faradic bath. The galvanic form need never be resorted to but for a special object.

Trautwein has devised another means of general electrisation, comparable to the electric bath. It is called the *electric douche*, and consists of a stream of water connected with one pole of a galvanic or faradic current and allowed to play upon the patient's body, while his feet are in contact with the other pole. It remains to be seen whether this method has any considerable advantage.

In conclusion I have to mention two other methods of treatment, which have a more general application and are supported by abundance of clinical evidence in their favour.

1. The first is the *galvanic treatment of points of pain and pressure*—that is to say, of pressure points which, themselves more or less free from pain, evidently exert an influence in the production or relief of neuralgias and spasms—or of painful spots which become apparent under pressure of the fingers or electrical exploration and are associated with the other symptoms of spasm—neuralgia, tabes dorsalis, &c.—and in which the symptoms are not momentarily affected by pressure upon these spots.

R. Remak was the first to call attention to these spots and to point out their great importance from a therapeutical point of view. He has met with them in many forms of neuralgia situated near or upon the vertebral column, and also in the neuralgia-like pains of tabetics ; and he has succeeded in producing a wonderfully soothing effect by stabile application to them of the positive pole. He has observed the same thing in several kinds of spasm—notably in facial spasm—where he applied the current to the spots at which he found he could control the condition by means of pressure. These are situated at a variable distance along the nerve trunk, and usually over the spinal column or in the neighbourhood of the cervical transverse processes. He ascribes the effects of electricity in these cases partly to its influence upon the sympathetic ganglia and partly to indirect catalysis. Many observations of this kind in connection with tabes are reported by Onimus and Legros.

Since that time Mor. Meyer has directed his attention to those points of pressure and pain over the spinal column, in the situation of the bony prominences, and especially of the transverse processes, and he has found them very common in many neuroses. He ascribes their presence to various structural changes—periostitis, neuritis, small glandular abscesses, inflammatory exudations, &c.—and believes that they are intimately connected with the neurotic phenomena to which they often give rise and maintain. He too prescribes galvanic treatment and the application of the positive pole to these pressure points as an excellent remedy in the various forms of neuralgia, spasm, chorea, writer's cramp, and even tabes dorsalis. Mor. Meyer has recently discovered similar spots in the plexuses and other parts in the course of the nerves, and for the treatment of these he has found the positive pole equally efficacious. He recommends that weak currents (4 to 8 cells) should be used at first, as likely to prove in many cases of more benefit than stronger ones.

By means of electrical exploration, which is very suitable for the discovery of these painful spots, Rosenbach found quite a number of them in chorea minor—over the vertebral column, in the neck, and at several parts of the chest—and here again galvanic treatment was attended with excellent results.

More lately Brenner has described such painful spots in the situation of the spine as occurring in sciatica, tabes, &c. He determines their presence by passing the galvanic K slowly along the spine with a current strength sufficient to be clearly appreciable to the skin without causing pain. At certain parts, which are often not more sensitive to pressure than others that are healthy, the patient winces with severe pain at the same time that the galvanometer indicates no considerable current strength. These spots are often in direct relation with the seat of the neuralgic or lancinating pains, especially in the case of girdle pains. Rational treatment with the positive pole gradually relieves the painful sensations, and usually cures the neuralgia and the girdle pains, at the same time effecting a notable improvement in the tabetic disease. Mor. Meyer has had such an experience in two cases of tabes. Voigt has also been successful in the treatment of this disease after the manner indicated.

For my own part, I have found these manifestations present in only a few instances, and I have often sought in vain for these pain and pressure points. In a recent case I saw the phenomenon clearly displayed, and here the result of galvanism was all that could be desired. Perhaps Holst's electrical treatment of ovarian hyperæsthesia in hysterics, with which also good results have been obtained, should be included in this class of remedies.

These facts at all events possess much interest, and should lead to further research. At present, however, they admit of no precise explanation, either with reference to the production of pain by pressure or the application of electricity at the situations mentioned, or their connection with underlying pathological states and the mode in which the galvanic current exerts a curative influence. The effects of this treatment, as recorded, are indisputable; its utility is beyond question and the matter deserves the closest attention. It is imperative that the points of galvanic tenderness be determined by means of the galvanometer after the method of Brenner. The best treatment for these points appears to be the *stabile application of the positive pole*, with a weak or moderate current. The negative pole may be placed at some indifferent situation or at some more distal centre of pain, according to circumstances. The operation should occupy from 1 to 5 minutes. It is needless to observe that this procedure should be supplemented by any other kind of electrical treatment which may seem to be indicated.

2. The other method which it remains to mention is one that has many advocates, and which in part has been extensively used. It is *galvanic treatment with weak currents of long-continued application.* They are currents of from 1 to 4 cells which are introduced into the affected parts, either by placing these in contact with the metal rheophores themselves or by means of suitable electrodes, and in this way their action should be continuous for hours, days, or weeks.

Ciniselli was perhaps the first in modern times to advocate the use of a 'simple element' of this kind for application to the skin in various nervous diseases. It consists of a pair of plates of zinc and copper, connected by an insulated wire (see fig. 27). These plates may be of different sizes, corresponding pretty nearly to our 'medium' and 'large' electrodes. They should be soft and flexible and brightly polished before each application. They should be fixed to the person at the part chosen by means of plaster or compresses, and care should be taken that their surface is accurately adapted to that of the body. Their action is promoted by placing beneath them a white linen cloth saturated with saline or acidulated water, and this should always be kept wet. I should observe that in this process the zinc represents the positive and the copper the negative pole. The plates may also be constructed of other pairs of metals besides these.

To secure the therapeutical effects desired the plates should be worn every day for several hours (2, 6, 12, or more), or even for whole days or weeks. If the skin is very sensitive purulent ulcers and abscesses may form beneath them. Their situation must then be changed and the period of application shortened.

These little instruments were found useful by Ciniselli in neuralgia, paralyses, headaches, &c. They cost but little; they are easily made of the shape and size required, and they can be worn during work.

Another method which is in principle the same as this has been employed on a large scale by Le Fort, who speaks highly of its efficacy. It consists of the use of a current of 2, 3, or 4 cells (pile Trouvé-Callot: zinc and copper elements without a diaphragm, or the small paper elements of Trouvé, or any other element of sufficient durability), which is passed into the affected parts by means of ordinary electrodes, and its action should be sustained for days and weeks with only short and occasional interruptions, finally at all times except during the night. The most suitable for this purpose are electrodes of tin, very flexible and of medium size. They should be covered with wash leather and kept damp with saline water. This may be effected by covering them with indiarubber sheeting; and they are retained in position by diachylon or bandages.

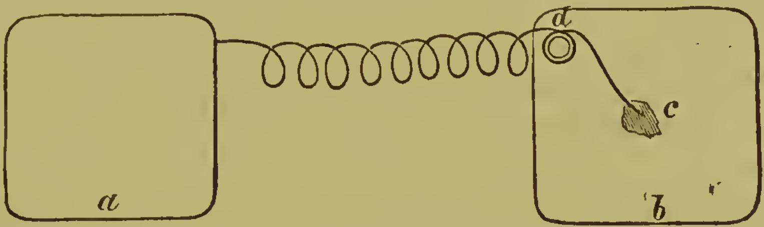

FIG. 27.—The 'simple element' after Ciniselli. *a*, zinc plate, in front. *b*, copper plate, behind, connected by an insulated copper wire of varying length. *c*, soldering. *d*, a small button round which the wire is wound to guard against ruptures, which are apt to occur.

Le Fort regards these weak currents as indicated in paralysis, paresis with simple atrophy or fatty degeneration of muscles, reflex paralyses in consequence of contusions, in every case of muscular mal-nutrition, and in states of rigidity. His results have been undoubtedly good, and his method may be substituted with advantage for many other forms of galvanic treatment that are in actual use.

Valtat has employed it in the atrophies, pareses, and paralyses of muscles that occur so commonly in connection with joint diseases, and he reports remarkable results. They are indicated at the period when acute inflammation has subsided, or at the outset in cases of a chronic character. Valtat prefers the descending action of the current. Later the treatment may be supplemented by faradisation of the muscles.

Since Ciniselli's first publication I have often made use of these feeble and prolonged currents. I have recommended the simple element to several of my patients, and I have seen it prove useful. One of my colleagues, who suffered from writer's cramp, experienced relief during the day while he wore it. I have frequently applied it with advantage to the head in cases of headache or insomnia; but its benefit was most marked in several cases of hysterical neurasthenia of a severe form occurring in women of a delicate constitution. I made them carry the instrument upon the back for several hours every day. But it is difficult in such cases to allow for the moral effect of treatment. In a case of senile palsy it proved very efficacious. I have also employed Le Fort's method in many cases of atrophy of the quadriceps due to inflammation at the knee, and in one instance its benefit was very marked.

This procedure therefore seems to me to merit further attention. But how far is it to be regarded as analogous to the so called 'electric' chain of Pulvermacher and others, for a long time so much in use, and by means of which Hiffelsheim among the rest appears to have performed many cures? Do these and other such contrivances—as, for instance, N. Mayer's little columns—furnish currents which are really sustained and sufficiently active? These are things upon which I can form no judgment, for I have no acquaintance with them and they play an unduly prominent part in the jugglery of quacks and charlatans.

I think I am not concerned here to discuss the phenomena of metalloscopy, which some observers have attempted to explain by the influence of very weak electric currents.

LECTURE XV.

General Principles and Technical Considerations for Treatment by Electricity—Treatment *in Loco Morbi*—Localisation of the Current—Localised Faradisation of Motor Nerves and Muscles—Systems of Treatment—Personal Acquaintance with the Effects of the Currents—Choice of Strength of Currents—Choice and Disposition of Electrodes—The Elimination of unnecessary Excitations—Frequency and Duration of the Sittings—Total Duration of Treatment—The Treatment in the Hands of Laymen.

Before passing to the Special Part, in which we shall treat of the indications of electricity in disease and the various modes in which it may be applied in different disorders, I would direct your attention to certain general principles and special precepts for its use. They are the result of a long experience, and though they may seem to you now to be of little interest and importance you will find by-and-by that an acquaintance with them will amply repay the trouble you may take in acquiring it.

The first great principle is that of the treatment *in loco morbi*—that is to say, the direct application of electricity to the affected part itself. We are in the fortunate position, as compared with other branches of medicine, that we can apply our remedy at once to the seat of disease, and in quantity and intensity such as we can absolutely determine and control. And this power, there can be no doubt, is of the greatest importance in the generality of cases. The fact, however, though long recognised, is not sufficiently appreciated, and every day we see it ignored or overlooked. An inherent obstacle to its application arises from our faulty means of diagnosis. How often are we in doubt as to the exact localisation of nervous troubles! and how often are we unable to specify the precise situation of the *locus morbi*! There is not a single neuropathologist of experience but has had many difficulties of this kind. But wherever we can satisfy ourselves of the situation of the focus of disease it may be taken as the first great rule that if electricity is to be used that is the place to apply it. Failing an accurate knowledge of this point, it is only left to subject each of the possible localisations to the systematic action of the current, and in doing this the best plan is to proceed from the periphery inwards. There is but one—and that only a seeming—exception to this general rule. It is the case in which we aim at effecting a cure indirectly—for instance, by reflex influence, or indirect catalysis, or the so called galvanisation of the sympathetic. In such a process too our object is to work upon the seat of disease, but in a roundabout way, and we are very successful in this. This, however, is a very different thing from attempting to cure a paralysis of brain origin, for example, by faradisation of the paralysed muscles.

It is especially important to keep this principle in view in the treatment of certain symptomatic disorders consequent upon local diseases, as paralyses, anæsthesias, contractures, pains, and the like, and in these, too, much depends upon a judicious choice of the place of application of the current.

In more disseminated or general neuroses, constitutional affections, and the like, or where it is desirable to bring about a certain result by acting upon the nervous system as a whole, or upon the nutritive processes, local treatment by electricity of course is not called for. The methods lately described (Lect. XIV.)—general faradisation and galvanisation, the electric bath, &c.—find here their appropriate sphere of action.

It is a necessary consequence of the principle which I have laid down above that we should endeavour to determine *the most exact method of current localisation*, so as to be able to effect our purpose thoroughly and completely. In order to do this the great requisite is a sound knowledge of physics, and above all a practical acquaintance with the laws of Ohm. You must know where and how to apply the electrodes, of what size they shall be, the strength of current requisite to produce the desired effect in different parts of the body. For this it is evident too that an extensive knowledge of anatomy is needed; and much practice upon the living subject can alone impart that familiarity with the behaviour of the current to the different structures it has to traverse that is so necessary to its efficient application. Experiments to this end may be performed with advantage upon one's own body.

For the purposes of this exact localisation of the current in the nerves and muscles you will often need to refer to the instructions first given by Duchenne and afterwards developed by Ziemssen. For details I would refer you to the works of these distinguished writers. I will content myself by giving you here a brief sketch of the process of local faradisation of motor nerves and muscles, with the aid of drawings and a few remarks in illustration.

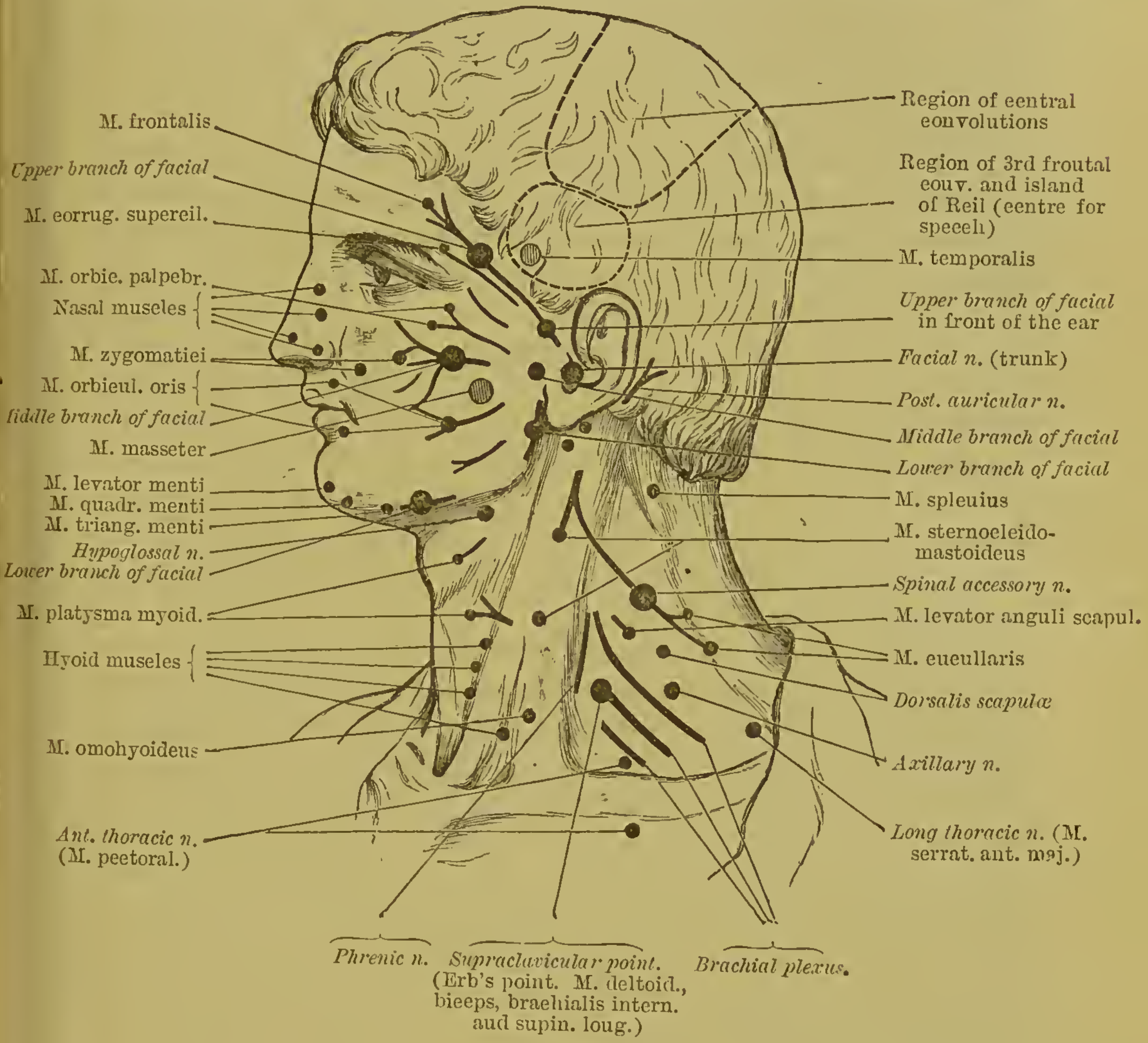

FIG. 28.

In the head (see fig. 28) the consideration of chief importance is the distribution of the facial nerve. It is often the subject of precise electrical exploration, and it can be excited with ease and certainty.

The drawing gives some idea of the ramifications of the facial. The principal points for excitation are marked also. In precise exploration it is well to begin by investigating the nerve trunk. This is best done by means of a fine electrode, which should be passed from behind forward below the external auditory meatus, and upwards along the border of the lower jaw. When this is done with a strong current marked contractions occur throughout the entire facial region. The same effect can be produced by a fine electrode within the external auditory meatus by passing it in a direction inwards, downwards, and forwards.

For the purposes of a comparative and more accurate exploration it is my custom to divide the facial into three chief branches—or rather into three districts—and to examine each in two points, one just in front of the ear and the other midway in the course of the branch in question. The highest of these branches belongs to the muscles above the palpebral aperture, the middle one to the muscles in front of the upper jaw, between the orbit and the mouth, and the lowest to the muscles of the lower jaw. It is true that the great variety in the distribution of the facial is an obstacle to its exact investigation; but I have tested this method practically times without number. The points of excitation for the exploration of parts behind the ear are situated over the zygomatic bone and close to the border of the ramus of the jaw.

For the excitation of a point midway in the course of the nerve I choose three places one above the other in a straight line—at the temple (and this is also the point chosen for excitation of the frontal branch in the general quantitative investigation of excitability), at the anterior extremity of the zygomatic bone, near its lower border, and at the middle of the inferior border of the horizontal ramus of the lower jaw. Then the separate muscles are taken into consideration. The appropriate points of excitation will be seen from the figure. They vary much in individuals, and it may be necessary to discover them by means of a fine electrode with a weak current. This is often painful, in consequence of the effect upon branches of the trigeminal.

The muscles of the eye are altogether inaccessible to electrical excitation. The muscles of mastication can be reached by direct excitation, as indicated in the figure. The occipital and the little muscles behind the ear are easily affected by excitation of the posterior auricular over the mastoid process.

In the neck a number of nerve trunks of size and importance engage our attention, as well as certain muscles, large and small.

The hypoglossal can be excited in many individuals by means of a strong current applied by deep pressure of a fine electrode above and behind the cornu of the os hyoides. The result of the proceeding is contraction, curving, and wrinkling of one half of the tongue, but no movement of deglutition. Direct excitation of the tongue, the soft palate, and the superior muscles of the œsophagus can be effected by the aid of a suitable electrode, which is best made with an interrupter in the handle.

The spinal accessory nerve is easily excited in a great part of its course. The deep mark in the figure indicates pretty nearly the point at which it is most readily excitable. It is also the point to be chosen for the quantitative examination of excitability. The two muscles which it supplies—the sterno-cleido-mastoid and trapezius—are easily excited separately. The first, however, occasionally offers some difficulty.

The splenius and levator anguli scapulæ may often be excited separately.

The various muscles of the hyoid bone and thyroid are rarely submitted to local faradisation. They will be found with very little trouble.

In the subclavicular fossa there are numerous nerve trunks and points of excitation gathered close together, viz. those of the brachial plexus and its branches and the phrenic nerve. The latter is difficult to excite separately. The operation should be performed with a fine electrode, so as to avoid the neighbouring nerve trunks, and because the electrode is with difficulty retained in position on account of the contraction of the scalenus and sterno-mastoid. The nerve runs somewhat superficially along the posterior border of the latter muscle. The effect of its excitation is a sudden inspiratory movement, a heaving of the epigastrium combined with an inspiratory sound in the larynx. It is effected better when the excitation is bilateral, produced by means of a divided kathodic electrode.

Artificial respiration in asphyxia, by rhythmical faradisation of the phrenic, was first practised systematically by Ziemssen under the direction of Duchenne. It is best performed bilaterally with the aid of large sponge electrodes (K divided and A at the sternum), both because by this means the phrenic is reached more effectually and also because the external muscles of respiration supplied by the branches of the brachial plexus are put in action at the same time. While this is done the head and shoulders and the upper parts of the arm should be fixed by assistants. A strong faradic current is then closed for one or two seconds, and again opened for a similar period while pressure is made upon the chest. This process is repeated; and so artificial respiration may be maintained for several hours, according to the statements of Ziemssen and others. Finally, the galvanic current (KC) may be employed for the same purpose.

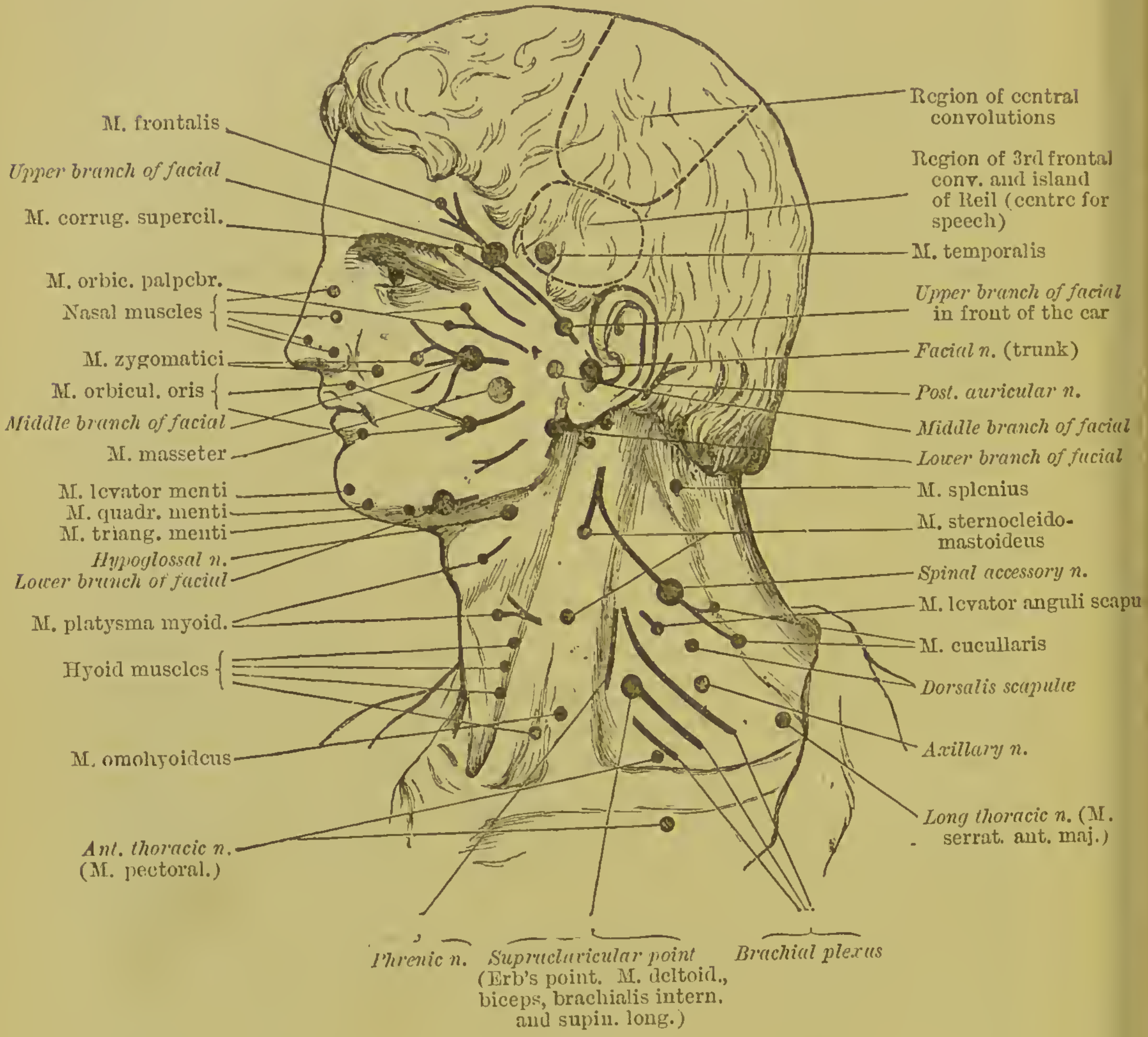

Fig. 29.

The different branches of the brachial plexus may be reached separately, with a little care, especially in persons of a meagre habit. For this purpose a fine electrode must be used with slight pressure, and the current should be carefully regulated. The upper extremity must be somewhat raised meanwhile, and the head turned slightly to the opposite side. In this way may be found the axillary nerve (for contraction of the deltoid) above, posterior thoracic (contraction of the rhomboids) a little posteriorly, the long thoracic (to the superior serratus) below and exteriorly. The latter nerve is also often excitable in the armpit and along its course in the thorax. Just above and below the clavicle, more internally, is the anterior thoracic (for the pectoralis major). The principal branches of the plexus, the median, musculo-cutaneous, and radial (less frequently also the ulnar) can also be excited in this situation, but not, as a rule, separately, with different combinations of muscles. Finally, at a particular spot about 2 or 3 centimetres above the clavicle, and a little externally to the posterior border of the sterno-mastoid, immediately in front of the transverse process of the sixth cervical vertebra, a simultaneous contraction can be produced in the deltoid, biceps, brachialis internus, and supinator longus, probably also in the supra and subscapular muscles (supraclavicular point of Erb, E. Remak, Hoedemaker). This point is of much practical importance.

In the upper extremity (fig. 30) the principal nerves on the flexor aspect may be sought out. In the upper arm the ulnar and median may be easily excited throughout their entire course in the bicipital groove. The point at which the ulnar is most readily excitable is a little above the internal condyle. This is also the place to be chosen for the purposes of quantitative electrical exploration. That for the median is at the elbow, where it lies somewhat superficially upon the flexors. The best position for excitation of these nerves is slight flexion (see figure), with the muscles as much relaxed as possible. A current of very little strength is sufficient. The effect of excitation of the ulnar is flexion and adduction of the hand, curving of the last three fingers, adduction of the thumb and a consequent conical shape of the hand. Excitation of the median is accompanied by pronation of the forearm, flexion of the wrist, clenching of the hand, and contraction of the thenar eminence.

The musculo-cutaneous nerve may easily be reached with a fine electrode, as it lies between the coraco-brachialis and biceps. In the forearm the two principal nerve trunks are readily found just above the wrist. The points where they are most easily excited are shown in the figure. The ulnar lies beside the tendon of the internal ulnaris. The median has often to be sought for with a fine electrode between the radialis internus and palmaris longus.

The muscles are more or less easily excitable at their respective motor points. That for the deltoid (anterior portion) is close to the clavicle; the biceps has two; the brachialis internus can be separately excited only by means of a fine electrode inserted beneath the relaxed biceps, while care is taken to avoid the median. The long and

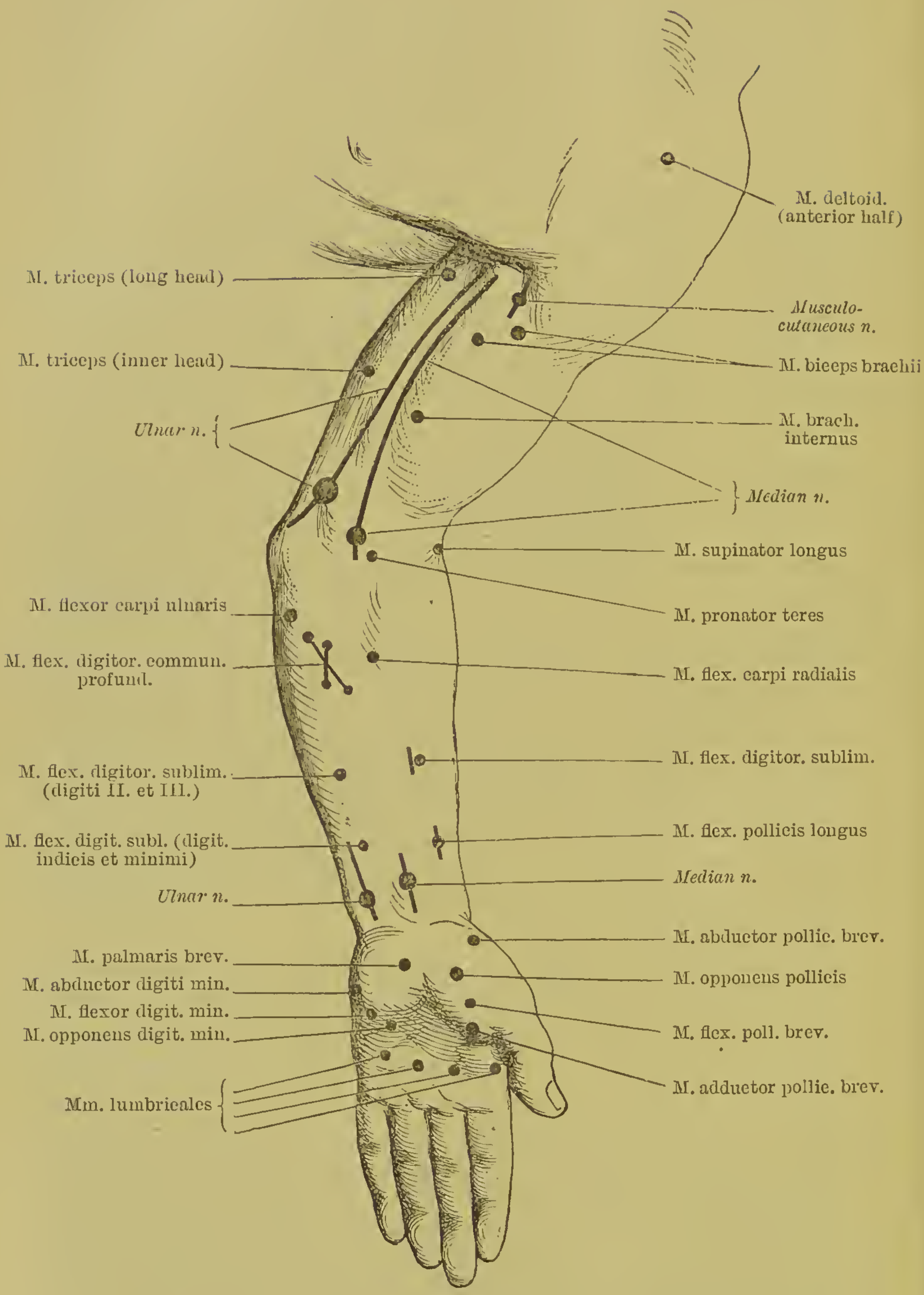
M. deltoid. (anterior half)
M. triceps (long head)
Musculo-cutaneous n.
M. biceps brachii
M. triceps (inner head)
M. brach. internus
Ulnar n.
Median n.
M. supinator longus
M. pronator teres
M. flexor carpi ulnaris
M. flex. digitor. commun. profund.
M. flex. carpi radialis
M. flex. digitor. sublim.
M. flex. digitor. sublim. (digiti II. et III.)
M. flex. pollicis longus
M. flex. digit. subl. (digit. indicis et minimi)
Median n.
Ulnar n.
M. abductor pollic. brev.
M. palmaris brev.
M. abductor digiti min.
M. opponens pollicis
M. flexor digit. min.
M. opponens digit. min.
M. flex. poll. brev.
M. adductor pollic. brev.
Mm. lumbricales

FIG. 30.

inner head of the triceps are easily acted upon at the points indicated.

In the forearm it is difficult to bring about the separate action of the different flexors. Their several points must be sought for carefully, and the places marked in fig. 30 will serve as a useful guide for the purpose. The excitation of the flexor sublimis digitorum is especially difficult. The small muscles of the hand are easily acted upon, especially when the cuticle is thin. A strong current and a fine electrode may be needed. The lumbricales are often difficult to excite, and the process is painful, on account of their proximity to cutaneous nerves. The forearm and hand may be studied with advantage by the physician on his own person.

In the axilla the large nerve trunks are always easily to be separated, and this is often of great importance in diagnosis. So we can act upon the radial, the axillary, and the long thoracic, excitation of which causes the characteristic position of the scapula, due to the action of the serratus.

In the upper extremity, on its posterior aspect (fig. 31), the radial in the upper arm is of chief importance, and its excitation at the place where it turns round the bone is attended with some difficulty. It should be sought for about midway between the insertion of the deltoid and the external condyle. At this point a fine electrode should be pushed down deeply between the triceps and brachialis anticus towards the bone, where a small spot may be found, which readily escapes the electrode, and where the nerve is easily excitable. Its excitation is followed by supination of the forearm, extension of the wrist and of the first phalanges, spreading of the fingers, and abduction of the thumb.

There remain on the posterior aspect only motor points of muscles—one for the hinder portion of the deltoid, usually two for the outer head of the triceps, and one for the brachialis internus (a branch of the radial). Then in the radial part of the forearm it is instructive to seek for the motor points of the supinator longus, the radialis externus longior and brevior, the different portions of the flexor digitorum, the ulnaris externus, the extensores indicis and minimi digiti, the extensors and long abductor of the thumb. The supinator brevis cannot in many instances be excited separately or at all. It can be reached readily only when the extensor of the fingers is atrophied or insensible to faradism, as in lead poisoning.

In the trunk there is seldom much to be done with electrical exploration. On the anterior aspect the intercostal and abdominal muscles cannot be made to contract completely, but a partial contraction may be produced by excitation at several motor points. The muscles of the back and those attached to the scapula are usually excited directly, and possess no well-marked motor points. The

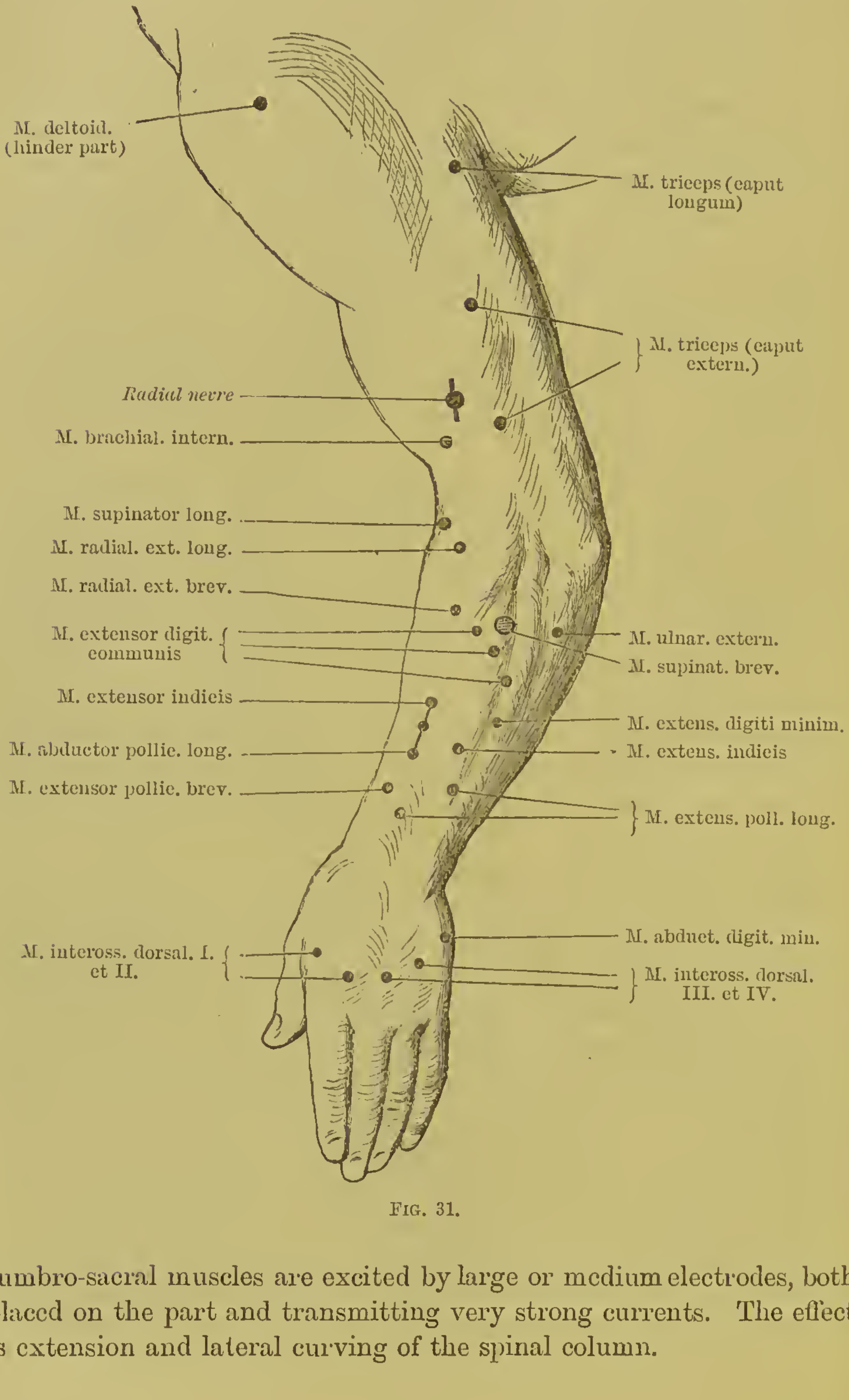

FIG. 31.

lumbro-sacral muscles are excited by large or medium electrodes, both placed on the part and transmitting very strong currents. The effect is extension and lateral curving of the spinal column.

In the lower extremity, at the anterior surface of the thigh, the crural nerve may be found a little externally to the course of the femoral vessels. The electrode should be applied high up against the pelvis, and a strong current employed. The effect is complete contraction of the quadriceps and sartorius, extension of the leg, and protuberance of different muscle bundles. The obturator can be excited only by pressing a strong electrode deeply among the muscles towards the pelvis, at the point indicated. The effect is complete contraction of the adductors. Separately the muscles are nearly all easy to excite—the tensor vaginæ femoris usually at two points, the sartorius high up. The quadriceps is hard to reach; the electrode should be applied deeply and with pressure, and it easily slides out of position, in consequence of the muscular contraction. The rectus and cruralis are with difficulty excited separately. On the other hand, the vastus internus can be acted upon easily along a line close

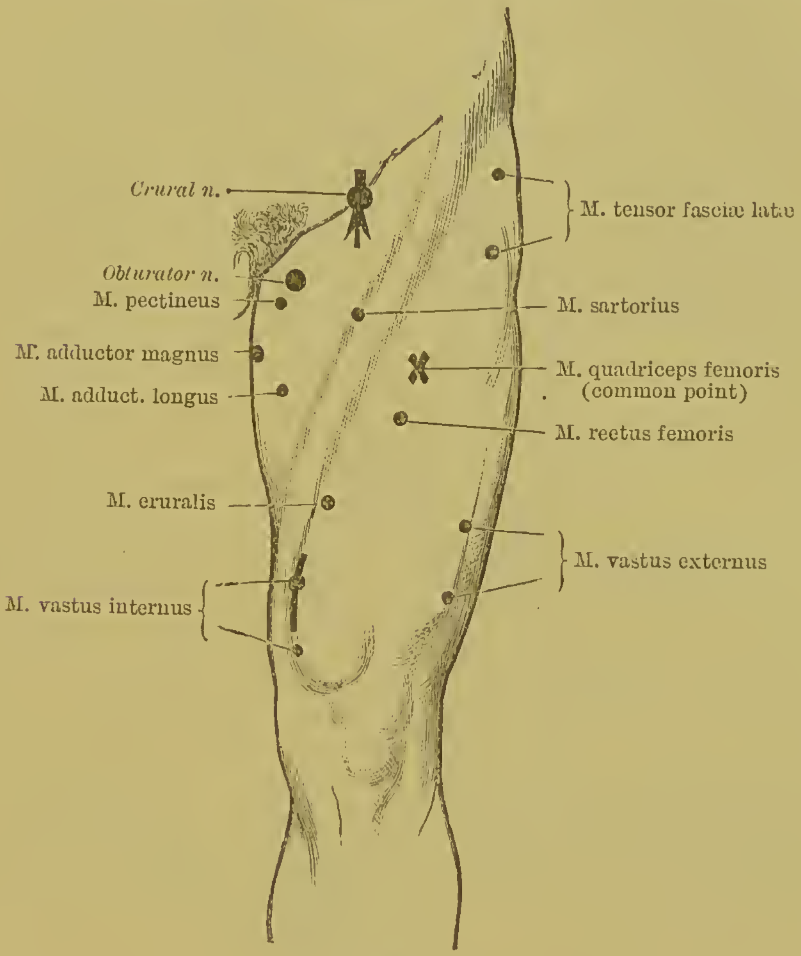

FIG. 32.

to its inner border; so too the vastus externus at two points on its outer edge. The adductors can be excited separately at the points indicated; the adductor magnus most readily at the posterior surface of the thigh.

At the posterior surface of the thigh the gluteus maximus can be reached only by direct excitation, and it has usually several motor points.

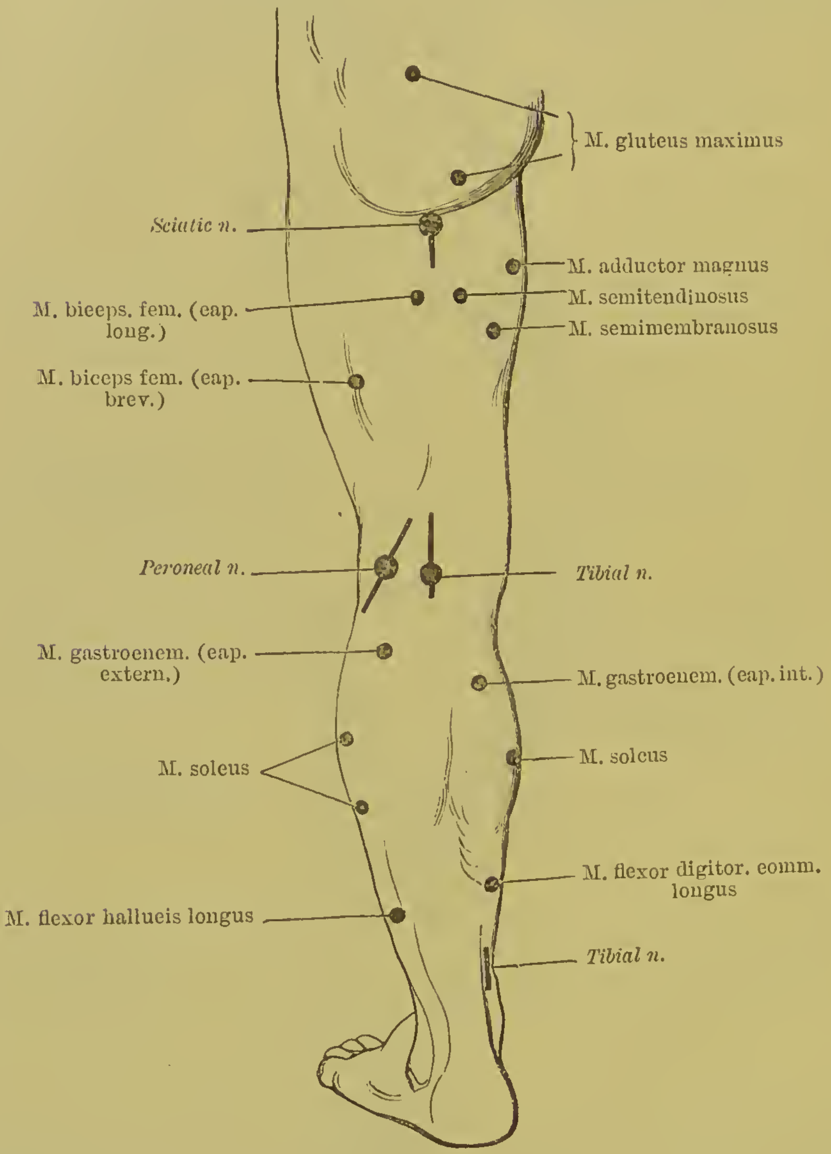
M. gluteus maximus
Sciatic n.
M. adductor magnus
M. semitendinosus
M. biceps. fem. (cap. long.)
M. semimembranosus
M. biceps fem. (cap. brev.)
Peroneal n.
Tibial n.
M. gastroenem. (cap. extern.)
M. gastroenem. (cap. int.)
M. soleus
M. soleus
M. flexor digitor. comm. longus
M. flexor hallucis longus
Tibial n.

Fig. 33.

The trunk of the *sciatic nerve* can be excited by firm pressure of the electrode just under the border of the gluteus and a powerful current. The effect is vigorous extension of the leg and foot, with preponderant contraction of the calf. The terminal branches of this nerve in the popliteal space are readily acted upon. In the middle is the *tibial nerve.* Its point for excitation is in the principal transverse fold of the space. Its excitation is followed by complete contraction of the calf, plantar flexion of the foot, and flexion of the toes. More externally and across the head of the fibula is the

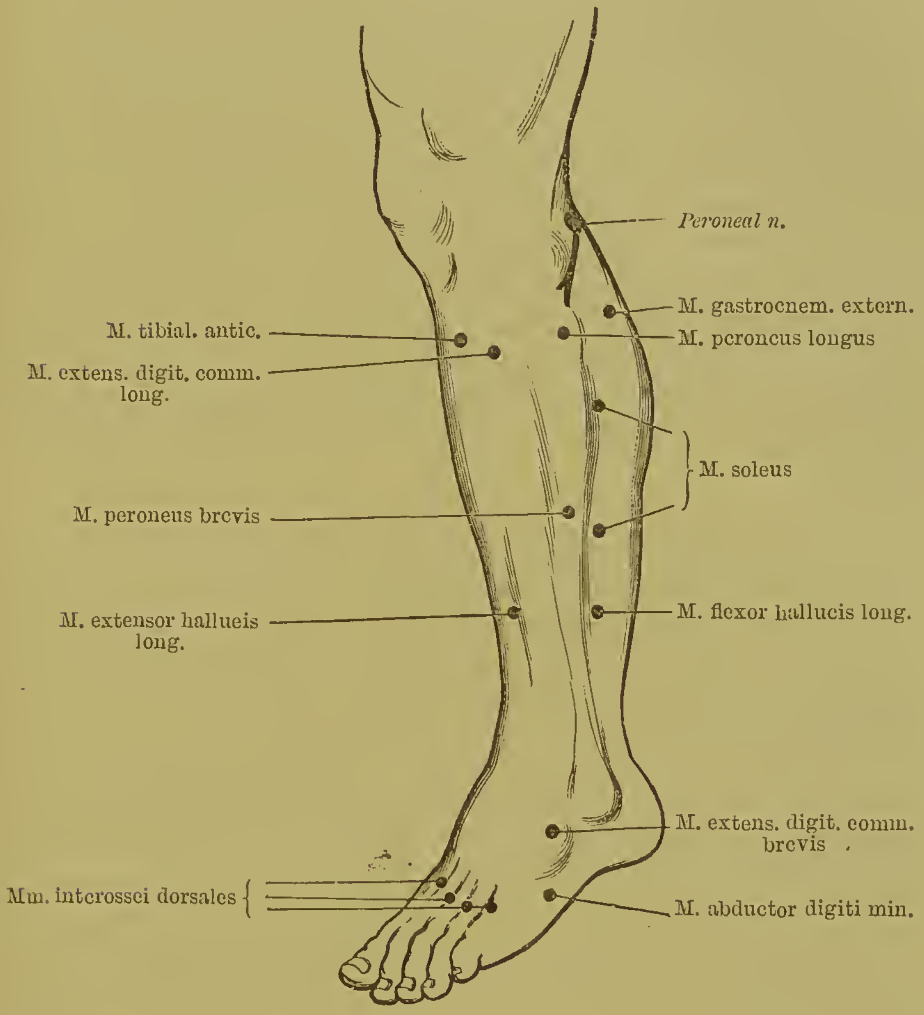

FIG. 34.

peroneal nerve. Its most excitable point—as also that chosen by me for the examination of quantitative excitability—lies also in the upper part of the fold mentioned above. Effect: strong dorsal flexion of the foot, with more or less abduction or adduction and extension of the toes.

The muscles on the hinder surface of the thigh are difficult to excite directly, and respond feebly. For the purpose the leg should be slightly flexed. The best results will be obtained in the neighbourhood of the points indicated.

In the leg we are most frequently concerned with direct excitation of the muscles from their motor points. *In the calf* those of the gastrocnemius and soleus are easily found. The latter has several points along its borders. Lower down and internally is that for the common flexor of the toes; externally that for the flexor pollicis. Lower still and internally to the tendo Achillis is the *tibial nerve*, by means of which contraction of the plantar muscles can be caused.

On the anterior aspect of the leg, above and close by the head of the fibula, the peroneal nerve is excitable. The motor points for the tibialis anticus, extensor communis digitorum, and peroneus longus are situated on the same level and require considerable currents. Farther down and externally is the point for the peroneus brevis; lower still, near the edge of the tibia, that for the extensor longus pollicis.

On the dorsum of the foot are the extensor brevis digitorum, abductor minimi digiti, and the dorsal interossei, which are all readily excitable. The muscles on the plantar aspect require very strong currents for their excitation and are of no diagnostic or clinical significance.

For the application of the current to the other parts of the body we must be guided by anatomical considerations. I shall revert to the subject in the special chapters which deal with it. The matter is one of much importance, but here I shall confine myself to a few elementary remarks.

In the skull it is necessary to know the situation of the different parts of the brain with reference to the surface. Thus, for instance, the region of the third frontal convolution (speech centre) should be looked for a little above and in front of the ear; the region of the central convolutions extends from this point backwards towards the vertex; the medulla oblongata lies between the mastoid processes and the auriculo-mastoid fossæ; the region of the great ganglia of the base is between the temples. The anterior half of the temporal region corresponds to the anterior fossa of the skull, the posterior half to the middle fossa. The posterior fossa with its nerves is situated between the mastoid processes. False impressions upon these subjects are common enough.

I have already pointed out (p. 258) the situation of the superior ganglion of the sympathetic in the neck. The inferior ganglion should be sought with a large electrode above the clavicle and close to the sternomastoid, the other electrode being placed opposite upon the spinal column.

In the *back* regard must be had to the position of the cervical enlargement (from third and fourth cervical to second dorsal vertebra) and of the lumbar (from tenth dorsal to second lumbar vertebra). The situation of the stomach and viscera, the cœliac axis, bladder, uterus, ovaries, &c., is sufficiently well known.

In every case you should conceive a definite plan of treatment. Indecision is most tedious and unsatisfactory. The method you adopt must be a rational one and chosen with reference to all the circumstances of the case. Sometimes you will suspend your treatment in order to observe its effect. If this is not apparent you will resort to another method—perhaps to several in succession. But you cannot be too much upon your guard against constant changes, for in this way you will obtain no positive results nor any data that can be utilised for scientific purposes.

I hold it as indispensable for anyone who would practise electrotherapeutics that he be thoroughly acquainted with the action and strength of the currents he uses. Make experiments upon your own body; verify the law of contractions in its different nerves; practise faradisation of all the parts that are within your reach. Become familiar with the sensations which the different current strengths (determined by the number of cells or the galvanometer) produce in the various structures and learn how the senses, the skin, and the brain react to electricity. It is only in this way that the requisite certainty and precision can be acquired

It is of the utmost importance that the current strength and density—in other words, the electrical dose—should be suitable to the case. It should be chosen with reference to the nature and seat of the disease, the part of the body to which it is to be applied, idiosyncrasy, the condition of excitability, &c. It is here that the principle laid down on p. 270 has its application. The injured part is to be submitted with the utmost attainable certainty to the action of a current of sufficient density. C. W. Müller has conferred an undoubted benefit upon science in formulating this axiom more precisely, and rendering it of greater utility by enabling it to be applied with ease and in a manner that admits of estimation and comparison. This, however, was first made possible by the institution of absolute galvanometers, and Müller has only carried out the suggestion which was made by me in the first edition of this book. He regards the current density as the most important consideration in the therapeutical use of electricity, and maintains that it should be accurately measured and regulated for every application and for each part of the body. For this purpose the density of the current may be expressed numerically in the manner we have already seen. Thus, for instance, $\frac{1}{20}$ means that the affected part has been submitted to an electrode of 20 square centimetres and a current strength of 1 ma.; $\frac{5}{70}$ means that the electrode was of 70 square centimetres surface area, and the current of a strength indicated by 5 ma.

Perhaps in this Müller lays too much stress upon the density, to the exclusion of other elements in the constitution of the current. Thus it may be that its strength—i.e. the quantity of electricity supplied to the body without reference to its density—has a certain influence in producing its effect. The current strength and density, however, are so intimately related for the purposes of therapeutics, and are together so aptly expressed by Müller's method of estimation, that it must be regarded as an excellent contrivance.

In practice an electrode will first be chosen of suitable size, according to the place where it is to be applied, the extent of the disease, its distance from the surface, and the like; and then a current will be taken of such a strength in ma. as to secure with this the required density. In my mind it is well to use only electrodes whose surface area may be expressed in decimals. In this way the numbers used are simpler and the results obtained more comparable than those of Müller, which involve such dissimilar quantities as $\frac{1}{18}$, $\frac{1}{7}$, $\frac{1}{11}$, $\frac{1}{13}$, $\frac{1}{46}$, $\frac{1}{28}$, &c. I also think that the current density, or dose (as it may be best termed, since this implies the current strength as well), should be indicated by placing as numerator the *actual* strength used in ma. and as denominator the actual size of the electrode, so that the statement of those fractions may show the true nature of both agents—thus, for instance, we should have such expressions as $\frac{1}{20}$, $\frac{3}{50}$, $\frac{4\cdot5}{70}$, $\frac{15}{100}$—and this seems to me a more practical and intelligible arrangement than if we were to reduce the fractions in each case, as Müller is accustomed to do. The electrical doses that are appropriate for each condition must be determined by research and experience.

Müller, who has had very large experience in this matter, and has lent himself to the task with the utmost assiduity, lays down as sufficient for most cases a current density of $\frac{1}{18}$; and, further, he attempts by a process which is obviously at variance with well-known physical facts to adapt the dose to the distance from the electrodes of the parts under treatment. In either case his prescription is altogether inadequate and almost smacks of homœopathy. It is useless to expect any principle of uniformity to obtain amongst the different conditions that call for treatment, but I will offer some suggestions of a general character that should influence you in the choice of the electrical dose.

In all cases it is well to avoid using too strong currents to begin with. The best way is to test the current beforehand on your own body, with the hand or at the face, and make trial in each instance of the resistance of the patient's tissues before you resort to currents of greater intensity. Under all circumstances it is advisable to have a galvanometer in circuit; without this the treatment is to some extent uncertain. When a galvanometer cannot be had sufficient information may be obtained by noting the sensation of heat which the current imparts to the skin, or by watching the appearance of an evident but not too well marked KCC.

Another point which should be attended to is the expediency of using only very feeble currents for application to the head, except where there are definite reasons for employing stronger ones, as often happens in connection with certain affections of the ear. Always begin therefore with currents of inconsiderable strength, because there is nothing that frightens the patient more than to have to endure suddenly and without preparation the effects of active excitation upon the organs of special sense or the brain, as flashes of light, dizziness, and the like. In operating upon the head abstain as much as possible from sudden interruptions or reversals, unless they are expressly indicated. The best plan, especially in dealing with persons of a delicate constitution or with patients of an apoplectic tendency and atheromatous vessels, is to apply the current gently with the aid of a rheostat, or at any rate to observe great care in placing and removing the electrodes. In this way you will spare your patient much suffering and yourself a great deal of annoyance.

In using the galvanic current it results from what has been previously said that you should make it a rule to have your electrodes as large as possible, especially when treating deep-seated structures. When I began my studies I used only the small, round, button-shaped electrodes which were then in vogue. I very soon became convinced that these were not large enough, and in this way I came to adopt those designated as 'medium' and 'large' (Lect. III.), which now I employ almost exclusively, although there is sometimes occasion for the 'very large' size. It is well therefore, unless where a fine electrode is needed for some special purpose, to choose in all cases the largest that anatomical conditions will permit. And they should always be kept well soaked. Warm water is the best for this purpose.

Make it a point to handle your electrodes with vigour and dexterity. Above all things apply them with coolness and precision when acting with strong currents. Nothing tends more to the discomfort of the patient than to receive repeated and unexpected shocks, such as result from a clumsy and undecided manipulation of the electrodes. This frequently happens with beginners.

I need hardly mention that you ought to avoid as far as possible all unnecessary excitation. Interruptions, reversals, and repeated closures are apt to be mischievous when they are not useful, and especially in the treatment of the central nervous system, in the use of electricity for the production of definite catalytic effects, for the cure of neuralgia and similar purposes. There are physicians who think that they have not done enough unless at each sitting they have caused at least two violent contractions by means of interruptions or even reversals of the current, so as to demonstrate unmistakably to themselves and their patients the potency and nature of their remedy.

Assuredly this is often a deplorable blunder, and the error had better be made on the side of gentleness.

You will often have much difficulty in making up your mind as to which form of current to use in a particular case. Neither the partiality of Duchenne and the French school for the faradic nor the enthusiastic preference of Remak and his immediate followers for the galvanic current has been borne out by riper experience. It cannot be said of either that it is suitable to all cases and every condition, or that it is invariably preferable to the other. Each has its appropriate function, and one will often succeed where the other has failed. We ought therefore to congratulate ourselves that both are at our disposal and that in each we have an efficient agent.

I shall make it my business in the Special Part of this course to point out to you the various applications of both forms of current. There you will learn that each has its own province, though it may not be clear in a given instance which current ought to be chosen and in what manner it should be employed. For the most part this knowledge results only from experience.

I may here allude briefly to a work lately published by Engelskjön which seemed at first to have an important bearing upon this subject, and especially afforded an unlooked-for and most gratifying promise of conferring great certainty upon our treatment, by determining the principles upon which the choice of the current should be made. Unfortunately, the very careful criticism to which this work has been submitted has tended materially to lessen the expectations which it at first aroused, and for this reason also it calls for only a passing notice here.

Engelskjön maintained that the two (faradic and galvanic) currents had a *dissimilar and contrary therapeutic action* in a large number of central affections, and especially in every form of vasomotor disorder; and he included amongst these vasomotor disorders nearly every disease of the central nervous system, so that in these cases only one current, the positive, exerts a curative effect, whilst the other, negative, but serves to aggravate the mischief. Now, to determine which of these is indicated in a particular case he says that this is to be done by experiment, the test being the improvement or the contrary effect produced by the simple application of a faradic or galvanic current to the medulla oblongata or the cervical part of the spinal cord, and this he says is manifested directly or after the lapse of a few days. It is to be discovered with equal ease and certainty by the effect of the current whether upon the eye or the omentum, and that, according to Engelskjön, with the selfsame method of application in either case. The positive (or curative) form of current enlarges the vision. The negative (deleterious or at least ineffective) form diminishes it (electrical examination of the field of vision). Furthermore, similar effects are to be derived indifferently in the omentum, morbid symptoms, and central neuroses, by electrising the skin with either current, sometimes in the same and sometimes in different ways, and this constitutes an element of very great complexity.

Proceeding upon the basis of certain vasomotor neuroses, the ordinary forms of hemicrania, and, above all, the protean manifestations of spinal and cerebral neurasthenia, and not without the aid of many very daring hypotheses, Engelskjön develops a system of treatment for nearly all the neuroses, which is at least a model of simplicity.

Having somewhat unhappily founded his exposition of the 'principles of electrotherapeutics' upon his interpretation of two very rare and obscure cases of cutaneous vasomotor neurosis, he enters upon the discussion of hemicrania—which he pronounces without hesitation to be itself a vasomotor neurosis—and then betakes himself to the still more misty regions of spinal and cerebral neurasthenia, where, as might be expected, he has no difficulty in effecting the most wonderful feats, and witnessing very strange results. In point of fact, none of these affections can be made the subject of clear and precise reasoning and well-founded conclusions. There are other 'reformers' in electrotherapeutics who would do well to bear this in mind. Some of the facts recorded by Engelskjön are well worthy of notice, if only they were confirmed, but the record of his researches abounds in exceptions and contradictions, which compel him constantly to fresh efforts at explanation.

But even upon matters of fact Engelskjön's statements are questionable. Notably those with reference to the electrical exploration of the field of vision for the purposes of diagnosis have been contradicted by Konrád and Wagner. And even if it be thought that this matter is still *sub judice* there can be no doubt that upon other points (movements of the eyelids, pose of the head, staggering, &c.) he has fallen into considerable errors, such as suffice to vitiate his conclusions and tend to discredit his views upon other subjects.

But he is not content with the statement of facts. He deals largely with hypotheses. He is possessed with the unhappy notion that nearly all the nervous disorders are due to vasomotor disturbances; even in the case of tabes, multiple sclerosis, and other forms of degeneration he postulates a 'preliminary vasomotor stage,' and this idea pervades all his views. He makes the boldest and most involved assumptions concerning these vasomotor changes as he imagines them to occur in pathological states. In explanation of his 'dissimilar' current effects, and of the exceptions to the principles which he lays down for the occasion, he heaps one hypothesis upon another until he is finally lost in the confusion that results. Each new fact as it arises threatens the entire edifice. He admits it with composure, and—continues still to build. And when, in conclusion, after five or six years' work he characterises his publication as the 'mere raw material' from which he hopes at some future date to elaborate the 'perfect images,' he has left such an impression that one cannot help wishing he had spent a few more years upon the undertaking, and presented his reader with the 'perfect image' in the first instance.

In spite of all this, there are many things in Engelskjön's book which are worthy of notice. It contains some germs of truth, and, if only for the purpose of verifying his statements, would repay the perusal of the young enquirer.

We come now to a question of considerable importance, and one that has not yet been satisfactorily settled. I mean the duration of the sittings and separate applications. Formerly, and especially at the time of the introduction by Duchenne of local faradisation, it was customary to have long sittings, lasting a quarter or half an hour, or even an hour and more. I have had, myself, as a young assistant to faradise a patient suffering from progressive muscular atrophy for two hours every day. It had the advantage at all events of providing me an opportunity of practising the art of local faradisation.

When the galvanic current came into use the sittings became gradually shorter. And this was not merely because the increasing number of his patients left the physician less time to bestow upon each of them, but because it came to be generally recognised that protracted applications were superfluous in most cases, injurious in some, and even at times productive of the worst consequences. At the present day physicians are pretty well agreed that as much or more may be done with short sittings than with long ones. Müller especially has of late proceeded upon this principle, and while he curtails the sittings to a very short term he protracts the total duration of treatment indefinitely. To the general statement conveyed here there are of course numerous exceptions. When engaged in the treatment of chronic articular rheumatism, the production of considerable catalytic effects, the performance of general electrisation, &c., we shall often be obliged to prolong the application. But you may bear in mind the excellent maxim of Beard and Rockwell: 'Much better too little than a little too much.' As a rule and under ordinary circumstances the best plan is to continue each separate application, i.e. the treatment of each part, for a period varying from ½ to 2 or perhaps 8 minutes at the most. The total duration of a sitting may vary from 2 to 15 minutes. It need not as a rule be longer. The patient should afterwards remain quiet for a little time (1 to 2 hours) and avoid exertion of any kind, so as to secure rest and ease to the parts that have been treated.

It is impossible to lay down a rule as to the frequency of the sittings. For the most part one a day will suffice, but there are exceptions to this, as, for example, in the case of severe neuralgias. On the other hand where you have to deal with affections of a chronic and persistent nature, remaining long under treatment, two or three sittings in the week will meet the requirements of the case. This of course will be decided by the circumstances in each.

It is obviously more difficult to predict, in a particular instance, the total duration of treatment. It is simpler to say that it will last till a cure is effected, and this may be in 3 days, 3 months, 3 years, or even longer.

In chronic cases, however, and in those which occur so frequently which are incurable in their nature, but admit of palliation and temporary relief, the question will often arise as to whether treatment should be continued or not. Such patients cannot be kept on hand for ever, notwithstanding that many practitioners display remarkable perseverance in this respect. In most instances their pursuits or the great expense offer an effectual bar to such a course. For contingencies of this kind you may take it as a general rule that it is well to go on with your treatment as long as it can be expected to yield satisfactory results. When this seems no longer probable you may discontinue it provisionally for a time. You will often find upon resuming it after an interval that it will prove more vigorous and efficacious than before.

In general, then, it may be laid down that these chronic cases should be submitted to treatment for 2, 4, or 6 months, and that then it should be suspended for a similar period, during which other remedies, as cold water baths, vapour baths, massage, and the like, may be resorted to with advantage. Or you might institute a series of 50 or 60 daily sittings every year, and you would find this an excellent plan in many cases of infantile paralysis, tabes, chronic myelitis, spastic spinal paralysis, hemiplegia, hysteria, neurasthenia, &c., where these diseases are of long standing. These considerations, however, it is needless to say, are influenced by other circumstances even more than by the exigencies of the situation from a medical point of view.

Finally, I ought to advert to a matter which is simple enough in theory but which in practice occasions a good deal of embarrassment. We are often asked, 'Who ought to carry out the electrical treatment?' Who is there that will bestow the time and patience which so tedious and seemingly monotonous a process requires? To my mind there can be but one answer —The physician himself, and if possible one who devotes himself to electricity as a special pursuit. One may have a general knowledge of medicine and be an excellent practitioner; but this is not enough, neither is it sufficient to possess a battery in order to become at once a skilful electrical physician. I think I have convinced you in my previous lectures that an absolute requisite is the possession of a great stock of special knowledge, and, I will add, a practical experience of no mean order. The practice of 'electrisation' is far from being as simple as it seems. It needs study and exercise, just as any other manual art does, and in addition it requires time and attention and a natural bent of mind. Of this I have had ample proof in the persons of my pupils and assistants. The medical practitioner cannot be expected to concern himself with electrotherapeutics. He is already too heavily burdened with other charges. The most that can be looked for is that he should be conversant with the principal features of this branch of treatment, so as to counsel his patients to resort to it in time and in the proper manner, as is done, for instance, with eye diseases. And if he will practise it himself he ought at all events to possess the indispensable qualifications. He should be able to administer to each case the treatment that will prove most efficacious, and I must enter my protest against those random performances, devoid alike of method and purpose, which serve only to impress the unhappy patient with the conviction that he has had enough of electricity.

There exist here and there abuses of a still more flagrant kind, which I would gladly see removed. Thus, for instance, a barber or a simple mechanic will furnish himself with a battery and proceed to electrify all manner of diseases promiscuously. If the vulgar sort throng in pilgrimage to a charlatan of this kind it is hardly to be wondered at, but when a physician sends his patients to such a quack with the simple instructions that they are 'to have themselves electrified' I have no hesitation in saying that he is guilty of gross negligence towards them. They are hardly less to blame who confide the task to incompetent nurses or hospital attendants.

We are often asked whether electrisation cannot be performed by the patients themselves, their relatives, servants, or attendants. The answer is imperatively no. Anyone who has had occasion to witness its performance in the hands of an inexperienced physician will be little disposed to confide in the skill of untrained people. Still it will occasionally happen that under pressure of circumstances and out of regard to the patient's sufferings this rule will be dispensed with. For my own part I have often been tempted to relinquish the treatment into the hands of the patient or his friends, but I have always had to reflect that little or nothing was to be gained by doing so. The thing is not so simple as might be supposed, and it is wonderful at times to witness the ingenuity with which in such hands the use of the current is perverted—suspended or misapplied. In simple cases and where the electrodes need only to be retained in position for a specified time the process can hardly miscarry; but in all that are of a more complicated character, and where regard must be had to physical and anatomical considerations, it is quite otherwise. Should it be necessary, in spite of this, for any reason to confide the treatment to the patient or his friends, it should always be in the first instance under the personal direction of the physician. Only the simplest and most reliable methods should be adopted, and they should be carried out in accordance with definite and precise instructions, which should be written if necessary.

And now, gentlemen, in concluding this part of our course I would again exhort you earnestly to improve every opportunity of acquiring skill and dexterity by the practice of electrisation upon your own bodies, while rendering yourselves familiar with the methods of exploration and extending your acquaintance with the physical conditions that must engage your attention.

SPECIAL PART.

SIXTH SECTION.

SPECIAL ELECTROTHERAPEUTICS.

Literature.—For this part, in addition to the works indicated in the separate lectures and the various manuals and textbooks of nervous diseases, see also the earlier works of Grapengiesser, Augustin, Hellwag and Jacobi, Bischoff, Ph. Th. Walther, Sundelin, Most, and others (see references on p. 3), which contain an admirable exposition of part of the subject; also

Duchenne (de Boulogne): 'De l'Electrisation Localisée et de son Application à la Physiol., à la Pathol., et à la Thérapeut.' Paris, 1855; 2nd edit. 1861; 3rd edit. 1872.—Becquerel: 'Traité d'Applicat. de l'Electricité à la Thér.' Paris, 1857.—Tripier: 'Electrothérapie.' Paris, 1861.—'Applications de l'Electricité, etc.' Paris, 1874.—Van Holsbeck: 'Compend. d'Electricité Médicale.' Paris, 1861.—Mor. Meyer: 'Die Electric. in ihrer Anwendung auf d. prakt. Medic.' Berlin, 1854; 2nd edit. 1861; 3rd edit. 1868; 4th edit. 1883.—B. A. Erdmann: 'Die örtl. Anwendung der Elektricität in der Physiol., Pathol. und Therapie.' 1856; 2nd edit. 1858; 4th edit. 1877.—Baierlacher: 'Die Inductionselektricität.' Nürnberg, 1857.—R. Remak: 'Galvanotherap. d. Nerven- u. Muskelkrankheiten.' Berlin, 1858.—'Applicat. du Courant Constant au Traitement des Névroses.' Paris, 1865.—Althaus: 'A Treatise on Medical Electricity, &c.' 1859; 3rd edit. 1874.—M. Rosenthal: 'Die Elektrotherapie: ihre Begründung u. Anwendung u.s.w.' Vienna, 1865; 2nd edit. 1872.—W. Erb: 'Galvanotherap. Mittheilungen,' *Deutsch. Arch. f. klin. Medic.*, iii. 1867.—Benedikt: 'Elektrotherapie.' Vienna, 1868; 2nd edit. 1874–76.—Brenner: 'Untersuch. u. Beobacht. auf dem Gebiete der Electrother.,' vols. i. and ii. Leipzig, 1868–69.—Seeligmüller: 'Ueb. d. Anwendung der Elektr. b. Krankheiten,' *Corresp.-Bl. d. Ver. d. Aerzte in Merseburg*, 1867, Nos. 6 and 7.—Fr. Fieber: 'Compendium der Elektrotherapie.' Vienna, 1869.—Pierson: 'Compend. d. Elektrotherapie.' Leipzig, 1875; 4th edit. 1885.—Tibbits: 'Med. Electricity.' London, 1873.—Russell Reynolds: 'Lectures on the Clinical Uses of Electricity.' London, 1871.—Beard and Rockwell: 'A Practical Treatise on the Medical and Surgical Uses of Elcctr., &c.' New York, 1871.—

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INTRODUCTION.

We come now to our chief task—the description of the action of electricity in the various diseases, the indications for the employment of this remedy, the formulation of the methods suitable for the different diseases and their innumerable modifications—in short, to *special electrotherapeutics*, with a view to which alone all our previous statements and investigations have been made.

I explained to you in the last few lectures that our electrophysiological knowledge, the many experiments recorded, and the knowledge we possess of certain pathological processes, as well as of the action of the electrical current, encourage us to look for many great results from the use of electricity; but I was obliged to add that we could have little or no certainty of an *à priori* kind, that we were always more or less on a purely empirical standpoint, and that electrotherapeutics proper is rooted in the soil of experience.

Hence it becomes our first duty to test the electrotherapeutic experiments most carefully, to find out whether they authorise the adoption of this remedial agent, whether they endure the control of the inductive method of investigation, and whether they may be used as a basis for the establishment of therapeutic indications.

This implies a critical sifting of our own experiments and of those which are collected so abundantly in literature—a task which can hardly be mastered, especially if we consider how many difficulties stand in the way of obtaining accurate therapeutic information, perhaps more in this subject than in any other. Apart from the subjective element which is in many respects inseparably connected with them, the partiality which most specialists cherish for their own treatment, and the more or less unintentional self-deception which is so often added to it, we have here to do with forms of disease in which even a conscientious and sceptical observer may succumb to the greatest delusions. So many alternatives are possible in nervous diseases, especially in the numerous functional neuroses; such remarkable instances of improvement and cure occur, as it seems, spontaneously; psychical causes, various external and sometimes entirely unknown influences, play so great a part here, that the 'post hoc ergo propter hoc' is especially apt to suspend the more rational principles of judgment. In other cases, again, the pathological processes are so tedious and the duration of treatment so long that it is not easy to estimate the therapeutical result with regard to the possibility of spontaneous remissions and improvements. Or it may be that other methods of treatment are not excluded, and the beneficial action of separate remedies, or the result of a course of baths and the like, may be put down to electricity. From all sides, therefore, almost insuperable hindrances to the attainment of accurate therapeutical data present themselves; and even the statistics of great numbers of experiments can hardly give a more exact conclusion, as the individual cases are apt to differ so much from each other, even when they sail under the same diagnostic flag, that they involve great sources of error. It is only the collected cases of a few careful observers which can claim to be of any value in this respect.

If, in spite of these difficulties, the more experienced do not entirely lose the hope of emerging from this sea of error, it is because so much that is cheering has shown itself in their experience, so much proof—often, indeed, subjective proof—to convince them of the beneficial action of electricity, as to furnish an invincible incitement to further labours and investigations in this arduous field.

But with a view to the scientific establishment of the results, and to the gradual construction of the foundations of a scientific electrotherapy, as careful a choice of cases as possible must be made; and from the superabundant wealth only those should be selected which rest on accurate and thorough observation, and in which, from the rapidity and extent of the cure, from the exclusive employment of electricity, and from all the accompanying circumstances, it may be inferred without doubt that the cure must be ascribed to the electricity *only*, and not to chance or other remedies employed at the same time. It is evident to all who know anything of the subject that such strictly sifted cases are still very much to be desired, and it is the chief duty of scientific electrotherapeutics to increase their number.

A second important problem, however, is the determination of the methods by which the electrical treatment may be most effectually conducted in the individual cases. And this problem, as you have already heard, is not to be solved directly by means of our knowledge of the physiological action of the various currents, although this will serve to guide us in our investigations, but only by the light of ample and critically sifted experiment. There can be no doubt that it is only an exact and scientific method that will attain our end, and that vague experimentation, without scheme or plan, will never furnish data of any value. He who applies one pole to the foot and the other to the hand of the same side in the treatment of myelitis dorsalis, or tries to cure progressive muscular atrophy by means of the faradic brush, and the like (as I have seen done) cannot expect to collect trustworthy statistics. Clear physical views must form the foundation of the method; these must be determined and guided by our physiological experience and our knowledge of the most important actions of the current, and, if these fail, we must turn to the region of pure empiricism; but experience must always have the last, deciding word, for only in this way can we come gradually to a complete and clear method of procedure.

I have endeavoured to treat of special electrotherapeutics according to these rules; but the longer I was engaged in the work the more I was obliged to admit the deficiency of our knowledge. Exact and positive facts are, unfortunately, too often wanting, and I acknowledge candidly that even my own experiments and numerous observations still show many shortcomings and gaps, which I am painfully conscious of, without being able as yet to supplement them. There is still much to be done in this direction after strictly scientific methods.

I must not omit to add that it does not seem to me to be in the interest of electrotherapeutics to draw as many diseases as possible into the domain of its action; it should not be had recourse to in every case where it may be of use, but principally where it deserves to have the preference over other remedies, in cases where it is very specially efficacious. It may be dispensed with in cases where we possess other and surer remedies; I should consider it very irrational, for example, to treat remittent fever with the electric current (which is not entirely without effect in the disease) instead of with quinine, to treat acute rheumatism with the faradic brush instead of with salicylic acid, or to give electricity a prominent place in the treatment of skin diseases and the like. Such indications must, of course, be simply disregarded, however interesting and justifiable it may be to investigate the action of the current in this field. Science need not lay any restrictions of this sort on herself, but the endeavour of practical electrotherapeutics must be to determine what forms of disease may first be subjected to electrical treatment, and in which electricity is the sovereign remedy, to be preferred before any other. It is only after this that diseases may be considered in which electricity possesses a subordinate importance, in which it may possibly be of some service, and so may be experimentally tried along with other remedies.

We shall keep this rule also in view in the following special consideration of the various forms of disease.

I. DISEASES OF THE BRAIN,

INCLUDING THE PSYCHOSES.

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LECTURE XVI.

Introductory Remarks—Physiological, Experimental, and Theoretical Basis for the Electrotherapeutics of the Brain—Therapeutical Facts—Collection of a Series of Personal Observations—Conclusions drawn therefrom—Negative or Partial Results—Description of the Forms of Disease in which Results may be expected from Electrotherapeutics and of those in which they may not.

VARIOUS prejudices have for a long time stood in the way of the direct application of electric currents to the skull in all kinds of brain disease. The occasional observations, published long ago, of the beneficial therapeutical effects of such treatment, especially the distinct assertions of Remak on this point, were received with decided mistrust and unbelief. On the highest authority (v. Ziemssen) it was affirmed, and pretty generally believed, that the electric current could not be conveyed to the brain at all through the cranial bones; while by others, on the contrary (Duchenne), the dangers of such an application, especially of the galvanic current to the head, could not be overestimated. What the one considered impossible the others declared to be very dangerous, especially for the brain and the organs of sense. After it had been established, through my investigations, that the first, physical prejudice rested upon error, and that the brain was very easily reached, even by weak galvanic and faradic currents, people learned gradually to renounce the physiological prejudice that the application of electric currents to the head had any special danger. Numberless investigations on the healthy and on the sick, especially the frequently practised investigation and treatment of the organs of hearing, often with very strong galvanic currents, proved the contrary long ago. The application of electric currents to the head is, without exception, well borne by the healthy. A certain amount of caution is of course necessary with a *diseased* brain; but the frightful stories of severe disturbances of the brain, apoplexies, amaurosis, and the like, in consequence of faradisation or galvanism of the head, have found no authentic corroboration.

We could therefore venture, with some confidence, to make diseases of the brain also the subject of electrical treatment, but it was necessary first to consider the question what justification existed for resorting to the employment of the electric current in disease of the brain and what grounds for expecting definite results from it.

A closer consideration shows that there are, indeed, many circumstances which should induce us to expect that electricity would often exert a favourable influence on the diseased brain.

Certainly the simple fact that electric currents in general act upon the brain, that they excite vertigo, stupefaction, and nausea, that they act beneficially on sleep, and the like, is a very inadequate reason for their therapeutical employment; this reason is, however, for many remedies of our pharmacopœia the principal and only one which regulates their employment in diverse organic diseases. Still we may at all events conclude from it that a stimulating and modifying action upon the cerebral substance is possible—that perhaps changes are effected in the molecular or finer nutritive relations; and a prospect is thereby opened up of aiming at a beneficial influence in functional disturbances of the brain, in conditions of weariness and exhaustion, as well as, perhaps, in morbid irritation, sleeplessness, psychical depression, &c.

More important data are furnished by the communications already mentioned with regard to the electrophysiological *influence on the cerebral vessels*—and in the first place the direct change in them (contraction and dilatation), which has been proved experimentally by Löwenfeld. There is thus opened up a more distinct possibility, at least, of accelerating or retarding the circulation within the cranium and in the brain by electric currents, of modifying the nutritive conditions, and perhaps of compensating pathological processes, as well as combating hyperæmia and anæmia (primary as well as secondary) with their consequences. According to Löwenfeld's experiments this may possibly be done directly; but the physiological grounds for the indirect vasomotor influence of the brain through the sympathetic and the cervical spinal cord are less sure, as has already been minutely pointed out (Lect. VII. p. 111 et seq.)

There are also a few facts pointing to the possibility of a still more indirect influence upon the cerebral circulation by reflex action through the skin; and the more recent experiments of Rumpf and the therapeutical experiences reported by him open up the prospect of attaining something in this direction too by means of the faradic brush (cf. p. 264). Some beneficial results attending the peripheral treatment with electricity in cerebral affections may, perhaps, be explained in this way.

Still more obscure are the probably molecular, dynamic influences exercised on certain cerebral functions through the sensory nerves, perhaps independently of the circulation. I will not touch here upon the metalloscopic experiments, although they are sufficiently remarkable, but will only call to mind the results of the researches of Vulpian, who saw cerebral hemianæsthesias—caused, no doubt, partly from anatomical changes in the brain—disappear after circumscribed local faradisation of particular portions of the skin of the forearm.

More sanguine hopes are, however, excited by the evidence of the catalytic action of electric currents, though they are firmly established only with regard to other parts of the body. Granted the possibility of directly influencing the brain and its parts, we are undoubtedly justified in assuming that these effects will not fail in certain diseased processes in the brain; and a great probability presents itself of our being able, by means of electric currents, to promote the absorption of hæmorrhagic extravasations, to assist the circulation of blood and lymph, removing œdema and collateral congestion, improving the nutrition of the parts, removing or limiting chronically inflamed, sclerotic, degenerative, and such like conditions—to which may be added a number of other therapeutical possibilities.

With the very considerable advance which the new nervous pathology has made in local diagnosis in cerebral disease, and with the unquestionable physical possibility of directing the electric and especially the galvanic current with tolerable certainty towards almost any portion of the brain, there is sufficient justification for therapeutical experiments in cerebral diseases.

If we look round to see what effect the many therapeutical experiments already made have had, what curative results they have given, we are met by the almost unanimous assertion of authors that in many cerebral affections the application of electric and especially of galvanic currents to the head, or to more distant parts, has indeed an undoubtedly beneficial action, either at once or after some time. There is certainly not a superfluity of proof of this view, which is more or less the expression of the subjective persuasion of the individual authors, drawn from extensive experience; but at the same time there is a considerable number of cases which ought to suffice, even for the sceptic, as a proof of electric curative action. I will cite a selected number of such cases.

1. *Observation by Neftel. Neurasthenia cerebralis.*—A busy physician, aged 42, suffering in consequence of excessive overwork loss of bodily and mental energy, capability for work greatly dimi-

nished, sleeplessness, dulness in the head, melancholic depression, distaste and inability to work or read, exhaustion, general weakness, feeling of weight in the lower part of the back. Examination gave negative results; a little albuminuria, without morphological constituents. Galvanic treatment: K to the nape of the neck; A stabile and slowly labile to the eyelids, forehead, temples, and auriculo maxillary fossæ on both sides; then the same with reversed electrodes and, lastly, galvanisation of the cervical sympathetic. Great improvement even after the first sitting, better sleep; final recovery; disappearance of albuminuria.

2. *Personal Observation. Emotional Neurosis; Right Hemiplegia.*—A merchant, aged 46. Severe emotional disturbance, in consequence of being insulted ten weeks previously; immediately afterwards gastric pressure, nausea, loss of appetite, subsequently vertigo, staggering gait: later on, increasing weakness and trembling in the right hand, so that the patient could not write, then general weariness and loss of tone, tendency to weep, depression of spirits, uneasy, sleep often very poor; memory impaired, thoughts often failing temporarily during speaking. Examination showed slight paresis of the right facial muscles. Tongue, palate, mastication, and deglutition normal, also ocular movements and pupils. Right arm decidedly weaker than left, marked tremor on extension of the hand, movements somewhat awkward and feeble, grasp weaker in the right hand than in the left (dynanometer: right 26°; left 51°). Sensibility of the right upper extremity normal, tendon reflexes somewhat increased. Motility and sensibility of the right lower extremity normal, tendon reactions and plantar reflex a little increased. Galvanic treatment: 6 elements Stöhrer from nape of neck to forehead; 8 elements to the cervical sympathetic: 13 elements K labile through the nerves and muscles of the right arm, daily.

June 26, 1879. Before the first sitting:

Dynamometer . . . . r. 26° l. 51°

After the first sitting:

Dynamometer . . . . r. 39° l. 44°

General condition better and sleep improved.

June 29. General condition changeable; improvement on the whole.

Before the galvanic treatment:

Dynamometer . . . . r. 32° l. 43°

After the galvanic treatment:

Dynamometer . . . . r. 42° l. 41°

July 5. Pain in the head, vertigo; sleep better.

Before the galvanic treatment:

Dynamometer . . . . r. 40° l. 41°

After the galvanic treatment:

Dynamometer . . . . r. 40° l. 43°

July 12. Patient feels better in the head and in speaking, and sleeps on the whole much better. Complains still of pain in the arm, which is stronger, but not yet quite strong enough to be used; the slight difference in the face still continues. Is obliged to leave the place.

3. *Personal Observation. Sleeplessness. Physical Depression.*— A widow, aged 41. Very much depressed in spirits for about two months, in consequence of emotional disturbance; pronounced precordial anxiety and almost complete insomnia (with unquiet thoughts, restlessness in the limbs, &c.) Some anæmia. Appetite and digestion good. Chloral and morphia not borne. Ordered in the evening baldrian tea and electrical treatment.

Jan. 21. Faradisation of the head with the hand.

Jan. 22. As yet no improvement; much anxiety; faradisation of the head, and also from nape of neck to epigastrium.

Jan. 23. Has slept 1½ hour; anxiety much diminished.

Jan. 24. Has not slept (on account of abdominal pain and diarrhœa).

Jan. 25. Two hours' sleep; abdomen all right again.

Jan. 26. No sleep (had seen friends in the afternoon).

Jan. 27. No sleep. Anxiety gone. Galvanic treatment now entered upon. 4 elements Stöhrer longitudinally from forehead (A) to nape of neck, stabile for 1½ minute; 6 elements from nape of neck to epigastrium stabile for the same length of time.

Jan. 28. 2 hours' sleep; anxiety permanently gone.

Jan. 29. 2½ hours' sleep; treatment continued.

Jan. 30 and 31. Has not slept (menses impending), but frame of mind very good.

Feb. 1. 3 hours' sleep.

Feb. 2. More than 5 hours' sleep; feels well. Menstruation commenced, causing 2 wakeful nights with migraine and tendency to feeling of anxiety. No galvanic treatment.

Feb. 5. Slept the entire night (7 to 8 hours)—for first time for six months. Galvanic treatment.

Feb. 6. 5 or 6 hours' sleep; anxiety completely gone.

Feb. 7. 7½ hours' uninterrupted sleep. No headache, no anxiety feels quite well. Leaves to-day. A subsequent communication shows the improvement to be continuous, with 4 to 5 hours' sleep every night.

4. *Observation by Rumpf. Hyperæmia of the Brain.* (*Neurasthenia Cerebralis?*).—A merchant, aged 47, without nervous tendency; formerly always healthy. In consequence of great exertion and excitement, first an unpleasant feeling of pressure in the head, then very ready flushing of the face and a feeling of cephalic congestion. Increasing weight and confusion in the head, at times severe headache; troublesome feeling of dizziness, especially in raising and depressing the head; singing in the ears; diminished capability for work; excitement, even upon small occasions; very poor sleep. Spinal functions quite normal. Objectively everything normal. Pct. brom. administered without result. Treatment: the faradic brush firmly applied over the back, chest, and upper extremities, followed by desire for sleep; head clearer. After a second similar application all symptoms disappeared.

5. *Personal Observation. Right Hemiplegia* (*from cerebral hæmorrhage*).—A carpenter, aged 25. On February 10, 1872 (at a ball), sudden onset of hemiplegia, without loss of consciousness or aphasia, but with indistinctness of speech (anarthria). Complete right-sided paralysis, even in the face; formication, but unimpaired sensation. Gradual improvement to the present condition. Formerly perfectly healthy. Condition on April 8, 1872: Right hemiplegia, paresis of the lower branches of the facial nerve, tongue slightly inclined towards the right, uvula straight, velum palati normal. Forearm very slightly movable, hand and fingers not at all; some motility in the shoulder joint. Slight contractility of the flexors of the arm. Both upper and lower extremities paretic and stiff, but patient can move about. Sensibility normal; some numbness in the finger-tips. Pupils and ocular movements normal. No aphasia. Heart quite normal. Galvanic treatment: Stabile longitudinally through left half of skull and transversely from left temple to right brachial plexus; the K labile through nerves of right arm. Next day distinct improvement reported. More accurate observation on April 9 showed: *Before the galvanic treatment*, complete immobility of the fingers; the hand can be raised only to an inch and a half from the nose and the hair on the temples. *After the treatment* (applied only to the head) the patient carries the hand easily to the nose and up to the hair on the forehead, *can bend the fingers a little*; movements of forearm somewhat easier. April 11: Patient feels marked improvement after each sitting, even in the leg, which has not been either examined or

treated. April 15: Progressive improvement; movements of the arm freer, bending of fingers possible to a small extent; patient grasps with ease the head and nose; the leg, which has never been treated, feels, in particular, freer and stronger after each sitting. August 1, 1872: Patient discharged to-day, very much improved. Gait almost entirely free and easy, motility of the arm much better, even in the extensors; no more contraction. Writing not yet possible on account of deficient pronation. Head clear. From the end of September patient could work again at his trade.

6. *Observation by Brenner. Cerebral Hemiplegia. Sudden and Marked Improvements in the Paralysis.* A merchant, aged 38, acquired syphilis in 1863; repeated relapses, irregular treatment. After about a year and a half patient waked one morning with complete right-sided hemiplegia, distortion of the face, and disturbance of speech. After four weeks complete paralysis of the right upper and lower extremities, with very moderate contracture, and paresis of the lower twigs of the facial, without cutaneous anæsthesia. After half a minute's faradic irritation of the muscles of the upper arm the patient could suddenly move the arm again, raise it from the trunk, and flex the forearm. The effect on the leg was still more marked; after some contractions had been excited from the crural nerve and the peroneal the patient rose up and walked about the room, with the foot dragging certainly, but without support. In the course of the treatment the paralysis improved a little more, but not very much, and permanent hemiparesis with contraction remained behind.

7. *Personal Observation. Right Hemiplegia. Sudden Improvement.*—An official, aged 53. Suddenly paralysed three years ago, without loss of consciousness. At first complete paralysis. Now the face normal; the leg still weak, patient walking only with a stick; arm almost entirely paralysed, with strong flexure contraction. Electrical irritability normal. Immediately after faradisation of the nerves and muscles of the arm patient can move his fingers somewhat better; this is also the case during the passage of a galvanic current transversely or vertically through the head. After this first (experimental) sitting considerable improvement ensued: the patient felt easier and stronger, could rise from his chair more easily and walk without a stick. Arm not improved. More prolonged electrical treatment did not add much to this suddenly occurring improvement.

8. *Observation by Neftel. Right-sided Hemiplegia. Aphasia (from embolism?).*—A man, aged 38. On February 23, 1877, severe apoplectic fit, leaving behind it right-sided hemiplegia and aphasia. Rapid improvement; remaining paresis of the lower and still more

of the upper extremity. Right-sided disturbance of seeing and hearing, pain in the head, melancholic depression, general weakness, sleeplessness, systolic bruit at the cardiac apex. Paresis of the right rectus internus oculi; limitation of the field of vision of the right eye in the form of a nasal hemianopia. Galvanic treatment from March 19, 1877: (1) K in nape of neck; A stabile and slowly labile on the eyelids, forehead, temples, and auriculo-maxillary fossa on both sides; 4 to 7 Siemens' elements. (2) The same procedure with reversed position of the electrodes. (3) Galvanisation of the cervical sympathetic (K on the ganglion). Immediate improvement: head clearer, sleep better; insufficiency of internal rectus disappeared, as well as defect in the field of vision; paresis of right extremities improved (they were only treated twice, more for diagnostic purposes). Discontinuance of treatment on March 29 (11 sittings). Relapse after some weeks, especially cephalalgia, vertigo, sleeplessness, pain in the right arm. Treatment resumed from May 29 (the same procedure); considerable improvement again even after 8 sittings.

9. *Observation by Moritz Meyer. Hemiplegia (probably from hæmorrhage).*—A merchant, aged 26. Feeble, suffering from palpitation, hypertrophy of the left ventricle without valvular lesion; vertigo, after a time unconsciousness, convulsions, and complete motor and sensory hemiplegia of the left side, with paralysis of the bladder. Very gradual improvement. Two years later left arm can be raised with difficulty to an angle of 70°; it is wasted, cold, and partly anæsthetic; moderate contraction of the flexures, considerable twitching, and dulness in the head; bladder in fairly good condition again. Treatment at first only galvanisation of the cervical sympathetic (A on the left superior ganglion). Result very satisfactory; after 12 sittings the arm can be completely raised and extended, and its sensibility has improved; the foot is dragged less, the head clearer. Afterwards ascending nerve-muscle currents; after 15 sittings the motility of the head and fingers very considerably improved; temperature of the arm permanently normal; sensibility not quite restored.

10. *Observation by Vulpian. Monoplegia of Right Arm with Complete Anæsthesia (probably from hæmorrhage).*—Workman, aged 18. Apoplectic fit, loss of consciousness; on recovery of consciousness right upper extremity completely paralysed. The paralysis is entirely confined to the right arm, with the exception of a very temporary aphasia. Besides the complete paralysis of the arm complete anæsthesia also exists. Various forms of treatment (arg. nit., auro-sod. chlor. faradisation and galvanisation of the paralysed arm)

produced only a very little improvement in the motility and sensibility. After 5 months the patient was treated by cutaneous faradisation (energetic employment of the faradic brush over a very circumscribed portion of the right forearm). Rapid improvement ensued in sensibility as well as in motility. The sensibility improved subsequently from day to day, the motility so much that in 20 days the dynamometer showed right 8°, left 57°. On one of the days following this the dynamometer showed on the right arm, *before* the faradisation, 10°; *after* it, 17°. After 5 weeks sensibility restored as far as the finger-tips, and all movements of the arm carried out without special exertion. After 2 months dynamometer showed right 35°, left 60°. The patient uses the right hand as much as the left: it is only a little weaker still.

11. *Observation by Althaus. Left Hemiplegia* (*from hæmorrhage?*).—A lady, aged 53. Two months ago apoplexy, with left hemiplegia. Walking now possible again, but the arm quite powerless; both arm and leg warmer than on the right side; contraction of the flexures, attempts at passive extension causing great pain. Increased faradic irritability. Application of the galvanic current to right temple, the superior sympathetic ganglion, and from the back to the nerves of the extremities, with reversals of the current. Remarkable effect on the muscular contraction; soon after the sitting the patient can extend the arm and open the hand; walking is also better; improvement lasting only a few hours. After 6 weeks of treatment (12 sittings) the patient can walk quite alone and has recovered the use of the arm to a great extent; the contraction and pain have disappeared.

12. *Observation by Althaus. Monoplegia of the Right Arm* (*from embolism?*).—A merchant, aged 52. Suddenly seized with a feeling of faintness and vertigo, and immediately lost entirely the use of his right arm; no disturbance of consciousness or speech; leg and face unaffected. Two days later complete paralysis of the forearm and hand, and almost complete anæsthesia of the hand and fingers. Application of the galvanic current to the left hemisphere for one minute, after which the patient can raise the wrist and move the fingers a little. Two days later improvement still continues, but has not made any progress; the repeated cerebral galvanisation caused again a slight improvement in the movements of the hand, but the addition of peripheral galvanisation of the radial and median nerves caused a further and more considerable improvement. Another galvanic sitting achieved a complete cure.

13. *Observation by Rumpf. Hemiparesis* (*anatomical diagnosis doubtful*).—A man, aged 36. Ill for several years; pains in the

back, right arm, and right hip; paræsthesia and weakness of the whole right side; inability to work, forgetfulness, dulness in the head, sleeplessness, low spirits; slight objective paresis of the whole right side, inclusive of the inferior portion of the facial; small amount of ataxy of the movements on the right side, distinct analgesia of the whole body; tendon reaction marked on both sides. On the left temporal bone a somewhat deep osseous cicatrix from a previous injury. Galvanic treatment continued for a long time without any result. Treatment with the faradic brush (on the trunk and the extremities) induced rapid improvement, pain and paræsthesia disappearing and sleep improving. After 6 weeks nothing left of the whole illness except a slight alteration in the position of the mouth, and a small amount of analgesia. Paresis disappeared.

14. *Personal Observations. Tremor Capitis; Attacks of Vertigo* (*commencing multiple sclerosis?*).—A shoemaker, aged 41; formerly healthy, never syphilitic. In March 1877 sudden and violent attack of vertigo, with subjective flashes of light; then loss of consciousness for two days; afterwards severe throbbing headache, pains in the back, and dragging pains in the legs. Each attempt at movement induces a lively tremor of the head, which disappears in a reclining posture. Gradual diminution of the tremor during the next few weeks and months, so that the patient could resume work. April 1878: Return of the severe vertigo, cephalalgia, dragging pain in the legs, stabbing pain and singing in the left ear; no disturbance of consciousness, but return of the tremor with much greater intensity. Improvement in hospital; condition during the following winter tolerable.

In the end of March 1879 another attack of vertigo, with severe pain in the head, but without disturbance of consciousness; again dragging pain and weight in the legs; very much increased tremor of the head, and now tremor of the arms as well, with difficulty in speaking, weakness of memory; diminution of the power of comprehension; eyesight also said to be weakened. Sleep disturbed; bladder and rectum unaffected. Condition on June 7, 1879: Nothing abnormal in a position of rest, but on any excitement or movement very active tremor and shaking of the head. Eyes normal even ophthalmoscopically. Otological examination showed an old affection of the tube and the middle ear. Tongue, palate, mastication, and deglutition normal; speech somewhat stammering and uncertain. No apparent abnormality in the upper extremities, except a slight uncertainty of movement and a little twitching on the left side; in particular no distinct tremor and no ataxy. In the lower extremities somewhat more pronounced uncertainty of movement, but still no distinct ataxia. Otherwise no objective abnormality.

Galvanic treatment: transversely and vertically through the head, and to the sympathetic in the neck. June 16: The trembling visibly diminished within the last few days; to-day no trace of the previous shaking movements. The patient also feels better subjectively; headache quite gone, now and then still some weight in the head; increased mental freshness, sleep better. Discharged completely cured on July 2, 1879. In October 1879 no more head symptoms; tremor permanently disappeared.

15. *Observation by Moritz Meyer. Left Hemiplegia after Acute Encephalitis.*—A boy, aged 8, acquired, in 1865, complete paralysis of the left half of the body, with loss of consciousness and severe convulsions. In May 1866 improvement in the leg. In January 1867 the arm still quite helpless, cold, and drawn towards the thorax; moderate amount of contraction. The deltoid and the radial region partially paralysed, the ulnar region completely. Electromuscular contractility intact; sensibility not affected. Treatment: Faradisation of the paralysed muscles. Considerable improvement after 13 sittings; after 42 sittings movements of arm and fingers almost normal.

16. *Personal Observation. Paralysis of several Bulbar Nerves.*—A labourer aged 48, suffering since June 1871 with pains in the upper extremities, rigidity of the lips, violent headache, seeing of sparks, and occasional diplopia. Later on pains in the nape of the neck; the head heavy and sinking forwards; increasing difficulty in mastication and deglutition. In autumn 1871 severe pains in the legs, also weakness in legs and arms; persistent and violent vertigo; singing in the ears. The voice feeble and hoarse, the tongue heavy; escape of saliva; tendency to ptosis; sleep bad, disturbed by pains and singing in the ears. Condition on June 30, 1872: Small amount of embarrassment of speech; voice weak. Pupils and ocular movements normal; no ptosis. Hearing on the left side destroyed, diminished on the right; constant singing in both ears. Oral muscles stiff and powerless; whistling impossible. Tongue cannot be protruded easily; distinct fibrillary contractions. Soft palate and uvula symmetrical, act with difficulty to reflex stimuli. Pain in nape of neck and back; position and movement of head normal. Deglutition embarrassed, mastication very much so. Sensibility everywhere normal. Tearing pains in right arm, the power of which is somewhat diminished; legs easily tired, &c. Galvanic hyperæsthesia of both auditory nerves; polypus in left auditory canal.

Galvanic treatment: 8 elements Stöhrer transversely through the temples and the mastoid processes; 10 to 12 elements to the cervical sympathetic; A stabile, with interruptions to each ear. Considerable improvement even in a few days. On February 3 little headache, legs stronger, tongue protruded better; patient can whistle again already; mastication and deglutition decidedly better. On February 12 continued improvement; head still somewhat dull, extremities almost free from pain; mastication, deglutition, and whistling quite normal; tongue protruded with ease. The further progress of the case very favourable, with the exception of some fluctuations. Discharged on March 27 (after 52 sittings) cured, with the exception of the aural symptoms.

17. *Personal Observation. Bulbar Symptoms* (Erb).—A man, aged 55, fell ill in February 1868 with tearing pains in the nape of the neck, slight headache; later weakness of the cervical muscles, so that the head could not be held upright. In the beginning of June increasing paresis of the muscles of deglutition, and simultaneous weakness of the upper eyelids; lastly, some difficulty in moving the tongue and embarrassment of deglutition. Otherwise normal. Condition in the end of June 1868: Peculiar position of the head, from paresis of the cervical muscles; double ptosis; considerable weakness of the muscles of mastication, the mouth generally open in consequence; motility of the tongue not markedly disturbed; fibrillary contractions present; flattening of the cervical muscles; extremities normal; galvanic hyperæsthesia of the left auditory nerve.

Galvanic treatment: 10 elements Stöhrer transversely through the mastoid processes, stabile; 10 elements to the cervical sympathetic, and K labile through the nervi accessorii and the cervical muscles. Upon this slow improvement. After 60 sittings patient decidedly improved; head held better, deglutition quite normal; mastication much better. Sent home from September 7 till October 30, under treatment with pot. iod. On readmission distinct improvement; position of the head decidedly better and stronger; ptosis less; deglutition and mastication quite normal; mouth no longer open. After 23 sittings more discharged on December 7, 1868, as nearly cured; position of the head normal, mastication and deglutition quite normal, &c.

The observations here communicated raise it above all doubt that cures can be effected in various brain affections by means of the electric current (and with very varying applications of it), and that these results are sometimes brilliant and rapid even in cases where other remedies have been employed for a long time and have been found more or less useless, so that our *à priori* expectations have been indeed realised in many cases.

But you must not think, gentlemen, that this is the case always, or even very constantly; it cannot and ought not to be denied, as every experienced medical electrician and neuropathologist will certainly admit, that a much greater number of cases with negative results must be set against these few brilliant positive cures; that very often the most rational and logical electrical treatment is ineffectual in cerebral diseases—too often because the nature of the disease renders it inaccessible to other modes of treatment.

There are, besides, the records of other cases which cannot be looked upon as definite arguments for the curative action of electricity, because in them the improvement has come on very slowly and gradually, often with the simultaneous employment of other remedies. The beneficial influence of electricity is by no means excluded in such cases; it is indeed extremely probable, but it cannot be accurately proved.

Finally, we often see cases (like Obs. 6 and 7, given above) in which, immediately after the employment of electricity, a very remarkable and rapid improvement in various directions sets in, but only reaches a certain point, where it comes to a standstill and cannot be advanced by further treatment. We see, for example, especially in cases of long-standing apoplectic paralysis, a striking improvement in the motility appear almost suddenly, after the first or the first few sittings. We see movements return which appeared completely lost; the patient can suddenly walk better, or use the hand much better, and he gives himself up to the joyful hope of a complete cure. But this hope is deceptive. After a short time there is an arrest again, and the improvement makes only slight progress or none at all. We may also see the sensory disturbances and paræsthesias, lesions of the organs of sense, aphasia, anarthria, &c., which have been associated with the hemiplegia, disappear very quickly under the electrical treatment, without corresponding improvement in the motility. In all such cases, often in a most surprising manner, a partial improvement will be attained, but even the most persevering continuance of the treatment will go no further. We have to do here, as Brenner has very properly shown already, with the removal of secondary disturbances—functional embarrassments induced by pressure in the neighbourhood of an apoplectic focus, by neighbouring derangements of circulation, œdema, inflammatory reaction, and the like. Secondary peripheral disturbances of nutrition in the nerves and muscles may, perhaps, also have some share in it, but the restitution of the activity of the *whole* disturbed or degenerated nervous tracts and centres is impossible, and an 'iron barrier' remains behind in the shape of functional disturbances. By means of the electric current the functional disturbances will only be reduced to the limit of the pathological lesion; but even with this a great deal is often gained for the patients.

There is, therefore, a *possibility* of the beneficial action of the electric current in numerous diseases of the brain even where a complete cure is excluded by reason of the nature of the affection.

After all that has gone before we may expect recovery by means of electrical treatment, with more or less certainty, in the following cases of cerebral affections:

Principally in the so called *functional* disturbances of the brain, in the various cerebral neuroses, for which we do not yet know any anatomical cause; the catalytic action of the current, its influence on the blood vessels and on the finer processes of tissue metamorphosis, probably comes into play in the first place, while the stimulating and modifying actions of the current perhaps effect something as well (as in the various forms of cerebral neurasthenia, in sleeplessness, cephalalgia, migraine, the slighter forms of psychical disorder, various forms of cerebral convulsions, chorea, epilepsy, cerebral disturbances in hysteria, &c.)

Further, in *circulatory* disorders, in which the influence of the electric current on the cerebral blood vessels, rendered probable by the investigations of Löwenfeld, may be utilised, as well as the more problematical indirect vasomotor influences from galvanism of the sympathetic, or reflexly from the skin, as in hyperæmia and anæmia of the brain, and in the disordered conditions supposed, in some cases erroneously, to be derived from them.

Next in *extravasations of blood* into the cerebral substance, and in the *centres of softening* resulting from thrombosis or embolism, in which a restitution of the destroyed, torn, or necrotic nervous elements can naturally not be expected even from the electric current, but in which a very beneficial influence may be presupposed on the absorption of the hæmorrhage, on the establishment of collateral circulation, on the prevention of secondary changes and sequelæ (circulatory and inflammatory disorders), on the improvement of nutrition, and on the re-establishment of the function of those nervous elements which are not quite destroyed.

Finally, a beneficial influence may be expected from the catalytic action of electric currents in all forms of *chronic inflammatory and degenerative processes* in the brain, in chronic meningitis and encephalitis, in sclerotic processes, and in the various forms of atrophy and degeneration of the nervous elements.

But a favourable influence seems to be decidedly excluded in the case of tumours and new growths in the brain, in the advanced stages of grey degeneration and sclerosis, in the callous thickening of the meninges, in the more severe forms of senile atrophy and softening, &c. But even here, especially when it has to do with forms which are otherwise curable, e.g. syphilitic gummata and the like, the electric treatment can sometimes act favourably on the secondary symptoms and sequelæ of the affection, from which part of the symptoms proceed, as headache, sleeplessness, confusion in the head, disorders of vision, paralysis, anæsthesia, difficulty of deglutition, &c.

LECTURE XVII.

Development of the Electrotherapeutic Methods—Direct Treatment of the Brain—Katalytic and Vasomotor Effects and the Methods of producing them—Stimulating and Modifying Influences—Method of Employment of the Galvanic and Faradic Currents in Cerebral Disturbances—Indirect Treatment of the Brain — Galvanisation of the Sympathetic — Reflex Influences from the Skin — Symptomatic Treatment — Electrodiagnosis in Cerebral Affections — Electrotherapeutics of the several Forms of Disease: Neurasthenia cerebralis; Insomnia; Hyperæmia, Anæmia, Cerebral Hæmorrhage; Softening of the Brain; Inflammation, Degeneration, Sclerosis, &c.; Bulbar Affections — Incurable Cerebral Affections.

More careful reflection shows that in the forms of diseases above mentioned we may count upon the vasomotor and catalytic effects of electric currents, but that we have less to expect from their simple stimulating and modifying actions. That is the same as saying that the galvanic current has a greater field of action in disorders of the brain than the faradic, although even to the latter all effects cannot be denied (Löwenfeld has induced dilatation of the cerebral vessels by faradisation of the head).

It results readily from our former physiological and therapeutical deliberations that various ways and methods are at our disposal for attaining our end in the electrotherapeutics of cerebral diseases. We may try to influence them *directly*, by a direct application of the current to the focus of the affection; we can strive to attain the same end *indirectly*, by means of vasomotor action, especially galvanisation of the sympathetic; or we can induce a beneficial effect *reflexly*, by means of peripheral irritation of centripetal tracts; and, lastly, an action through the special treatment of the *separate peripheral* parts whose function is disturbed (sensory and special nerves, motor nerves, and muscles, &c.) must not be omitted.

The methods by which these objects are to be attained are, indeed, as yet somewhat undeveloped. Until now the proceedings have been purely empirical, and it is only in the most recent times that a substantial physiological basis for these aims has been established. But even if this has been secured, so as to found a rational mode of procedure upon it, we have not gained much, as our knowledge of the more minute changes in the various pathological processes in the brain is so extremely scanty. We are, therefore, always driven back upon a careful empiricism even with the newer and clearer methods of working.

I shall describe in the first place the *direct* action upon the brain.

With regard to the katalytic actions and their sphere, the essential nature of the several pathological disturbances is as little known to us as the corresponding influences of the current from which we expect a cure. There is a lamentable uncertainty with regard especially to the mode of action of the one or the other pole and to the direction of the current; so that here only therapeutical experiments will avail.

On the other hand, with respect to the vasomotor action—the alteration of the circulation in the brain by electrisation of the head—the theories and experiments of Löwenfeld seem to furnish at least some indications. But it must be remembered that they were made only on rabbits, so that the results cannot be applied to men without further investigation; that they are not by any means constant, and are too ambiguous to be regarded as conclusive and certain; and above all that, even if we were sure of being able to bring about either one or the other change (increase or diminution) in the circulation of the brain, we should still very often be in doubt which was the desirable one to effect in the particular pathological case. Who would dare, for example, to say with certainty, in a case of hemiplegia after cerebral hæmorrhage or embolism, if it was better to induce hyperæmia or anæmia of the affected side of the brain? So long as we are not clear on such points (and, if I am not mistaken, we are still very far removed from certainty with reference to such cerebral affections) even with the aid of Löwenfeld's indications we shall not get beyond a cautious experimentation.

Having regard to these difficulties, and being clear as to the possible consequences, we may select the following methods of procedure—after Löwenfeld—for the influencing of the circulatory relations in the cranium and brain:—

For the purpose of a diffuse, uniform effect on the whole of the brain you may employ the vertical passage of the current with large electrodes in different directions, according to the effect desired. If you wish to increase the amount of blood going to the brain—to accelerate the circulation—A must be set on the nape of the neck and K on the forehead; but if you wish to lessen the supply of blood—to retard the circulation—then A must be placed on the forehead and K at the back of the neck.

For localised affections, on the other hand, a transverse or diagonal passage of the current is more suitable, the points of application being so chosen that the affected part comes in the direct line joining the electrodes. The choice of the pole for the affected side depends upon the indications present; if you wish to accelerate the circulation—to dilate the vessels—place A on the affected side, and *vice versa.*

With regard to the exciting and modifying actions of electric currents on the brain also we have not progressed much further than guesses and feeble experiments; the best of what we know has been discovered empirically. For who can describe with certainty the condition of the brain in the various neuroses, as irritation, or limitation, or paralysis? who can distinguish it from increased or diminished excitability, and who will trust himself to say if the anelectrotonic and katelectrotonic action of the poles occurs in the brain, and how far it will extend in a given case? So long as we have not progressed any further in these investigations all therapeutic attempts can be nothing but cautious experiments.

After these considerations, therefore, we remain essentially at this standpoint—that we wish to let the current act with competent force and sufficient intensity on the whole brain, or on the diseased portion, in order to attain a therapeutical result. In choosing the position of the poles and the direction of the current we shall of course be guided at the outset by our theoretical views (although they are supported by so few positive facts), but in general our task is to build up gradually a method of administration by a careful collection of experiments, and so by degrees to determine the most suitable procedure for the several categories of cases. The galvanic current will have to be considered by far the most frequently in such cases, and in the first place suitable electrodes and the proper positions for their application must be chosen. It is generally desirable to use 'large' electrodes, because the force of the current will thus be increased without adding to its density. I formerly used the 'medium' electrodes for transverse currents and the 'large' for longitudinal; lately I have employed almost exclusively the 'large head electrodes' (compare pp. 37–9), especially for diagonal currents.

The methods of application which I have hitherto used are the following:—

(*a*) *To act on the brain as a whole*, either longitudinally from the forehead to the nape of the neck or diagonally from the temple on one side to the opposite side of the neck and occiput (in this case of course on both sides consecutively). I apply the A nearly always to the anterior part of the head; since Löwenfeld's work, however, I would not oppose further trials with the poles reversed. Now and then, to attain a more unipolar action on the brain, I place a large head electrode at the vertex, or cause it to move slowly from the forehead to the vertex, while the other electrode is applied to the nape of the neck, or to the back, the sternum, one hand, or the feet; this is to be specially recommended for attaining a 'modifying' action.

(*b*) *To act on a local centre of disease* I employ in the first place a longitudinal current from the forehead to the nape of the neck on the same side (A on the forehead), then the transverse current through the affected part of the cranium—if the lesion is in the anterior cranial fossa, through the anterior temporal region; if it is in the middle fossa, through the temporal region immediately in front of the ear; and if it is in the posterior fossa (medulla oblongata, pons, cerebellum, occipital lobe), through the posterior auricular region (auriculo-maxillary fossa, mastoid process, and a little higher). I have lately employed the diagonal passage of the current a great deal, especially from the region of the temple, forehead, and vertex to the nape of the neck on the opposite side, and always in such a way that the diseased part shall fall in the direct line connecting the two electrodes. This application, made with the 'large head electrodes,' appears to me to be useful especially for acting on the motor cortical regions and the motor conduction as far as the pyramids in cases of aphasia, and also in lesions of the large central ganglia, in the pons, and medulla. I am in the habit here also of placing the anode on the side of the lesion, but further investigations with the kathode are to be desired.

For circumscribed, and especially for superficial, foci of disease (in the cortex, in injuries of the skull, &c.) the application of the one pole as exactly as possible on the spot, the other just opposite or on a distant part of the body, is to be recommended.

Similar or only slightly differing methods are employed by most writers; Neftel has described his particularly: he places one electrode stabile on the nape of the neck, whilst the other is passed slowly over the eyes, forehead, temples, and the auriculo-maxillary fossa, with reversals and a weak current. Neftel finds that the anode acts more powerfully anteriorly than the kathode.

The *faradic current*, which may be sometimes indicated, is employed according to the same principles, and with the same electrodes and points of application. For cases in which you may wish to make the application especially mild you may employ the so called 'faradic hand' for the treatment of the head. You use your own hand as an electrode (generally the anode of the secondary current), grasping the corresponding electrode with your other hand, and so allowing the current to pass through your own body. The hand to be used for the application should be well moistened, and it can then be applied easily to every part; it serves at the same time as a convenient test for the strength of the acting current; the other electrode can be applied anywhere on the patient—as the neck, sternum, hand. Löwenfeld recommends weak and long-continued currents for the faradic treatment of the head.

In this direct treatment of the head observe the following rules and directions:—

Employ only weak currents, and begin always with a *very* weak one. Do not neglect to test the strength by means of the galvanometer (currents up to 15° to 25° deflection with the insertion of 150 resist. or 1 to 5 ma. with electrodes of the diameter of 20 to 25 sq. cm., rather more with the 'large head electrodes'), or at least always advert to the flash of light and the vertigo, as a subjective measure of the strength of the current. This applies more particularly to the galvanic current; with the faradic stronger currents may sooner be resorted to, as with it an injury will not easily accrue to the brain, although, on the other hand, the sensory irritative action is more to be dreaded. Make no sudden closings and openings and still less reversals of the current. It is advisable to remove the electrodes by letting them glide slowly over the hair. Short sittings are imperative—$\frac{1}{2}$ to 1 or $1\frac{1}{2}$ minute in each situation, rarely longer.

For many cases it is advisable to make a few galvanic experimental sittings, as Richter has already recommended; you can thus find out easily if the patients will bear the application, and, very often, even whether it will be of service to them or not.

You will often be able to resort to indirect treatment in brain diseases, and here the first question to be considered is

Galvanisation of the sympathetic, which has been so much recommended and yet upon very slender ground. It is to be employed in every case where it is hoped to act on the circulation and nutrition of certain parts of the brain or of the brain as a whole. In one-sided affections the question is naturally raised whether only one sympathetic should be treated, and which—whether the one on the side of the lesion or that on the side of the hemiplegia and other symptoms. It appears at first sight very simple and obvious that only the former should be treated, but that has not by any means been found always to be the case, nor is the matter to be so readily decided.

In any case we cannot affirm with complete certainty that the sympathetic of each side influences only the corresponding half of the brain in its circulation and nutrition, and that it has not also a certain relation to the opposite half. It is also probable—which may be important—that the so-called sympathetic galvanisation acts upon other parts as well—on the base of the skull, the vagus, the cervical cord where decussation has already taken place to some extent. It appears, therefore, to be best in *all* cases, even in one-sided affections, to treat *both* sympathetics, as is obviously necessary in symmetrical or diffuse cerebral affections.

The best method is that usually employed (vide p. 263). I am in the habit of following most frequently the plan recommended by Moritz Meyer—K on the superior ganglion, below the angle of the jaw, and A on the opposite side of the sixth and seventh cervical vertebræ. Further experiments alone can decide whether the reversed position of the electrodes (anode on the ganglion, &c.) would not be more advisable.

Another method for the indirect treatment of the brain is the reflex impression from the skin; it may be tried when a special action on the circulation of the brain is desired, and may perhaps be of service in various functional disturbances—sleeplessness, psychoses, &c.—or in disturbances of the function of the sensory tracts in the brain (hemianæsthesia). You may effect this by exciting large surfaces of the skin (according to Rumpf), or circumscribed, localised patches (according to Vulpian).

In the former case you apply the faradic brush in vigorous strokes over the back, chest, and upper extremities, subsequently also over the lower extremities, for four or six minutes, the strength of the current being sufficient to excite flexure of the elbow when applied to the median nerve. If you wish to cause *contraction* of the cerebral vessels weaker currents will be sufficient, according to Rumpf's experiments; but if you desire *dilatation* of the vessels very strong currents must be employed. Great caution is, however, imperative in organic cerebral affections. But we cannot yet, with any degree of certainty, induce contraction or dilatation of the cerebral vessels at will in this way. Löwenfeld propounds the very convenient doctrine that the effect corresponds to the existing condition of the vessels—that dilatation is induced by cutaneous faradisation in pathological contraction, and contraction in pathological dilatation—but proof is wanting to this supposition.

In the other case (Vulpian) you apply the faradic brush for 8 or 10 minutes daily, with a tolerably strong current, to the skin of the anæsthetic or paralysed side over a very small surface, only a few square centimetres in size. The upper extremity (the external surface of the forearm) is to be preferred for this, as it appears to have a more marked reflex action on the brain than the lower. This method of treatment acts also very well in many cases which are not anæsthetic.

Finally, we may add, for many cases, a symptomatic treatment, i.e. a peripheral and direct treatment of the principal functional disturbances (paralysis, contraction, anæsthesia, aphasia, mental disturbances, &c.) This must be carried out in the special manner to be described in the following lectures, and can be done with the galvanic or with the faradic currents. Up to the time when we first ventured to treat the brain affection directly this was indeed the only method of electrical treatment of brain lesions; with the faradic current in particular we never sought to do much more than attack these disturbances peripherally. In paralysis, hemiplegia, and contractions we faradised or galvanised the muscles and the peripheral motor nerves; in anæsthesia, the skin; in aphasia and anarthria, the tongue and the lips; and so on. However surprising this may appear at first sight, it cannot be denied that a great number of results were obtained even by this method. Nor must we be embarrassed if we seek after an explanation of these results; for one thing reflex action must certainly be surmised, which partly falls upon the vasomotor tracts, and thereby obtains an influence on the lesion itself (perhaps also develops trophic action in an unknown manner), and partly is transferred to the paralysed motor tracts and exerts an antiparalytic action there, as I shall explain to you later in considering paralysis. For another thing it is easily conceivable, as Brenner has fully explained, that even in the peripheral parts, either in consequence of the cerebral lesion itself or on account of the long, compulsory rest and inactivity of the paralysed parts, various nutritive, molecular, or other disturbances are set up, which the electric current remedies; so that in this way also the functional disturbances will be reduced to dimensions corresponding to the anatomical lesion.

For this reason peripheral treatment must not be neglected in all suitable cases; and it is especially in old cases, which have not been treated by electricity, that we often see surprisingly rapid, even if only partial, results.

Before describing the special forms of cerebral disease which may come within the province of electrotherapeutics allow me to make a few short remarks on the *electrodiagnosis of cerebral diseases.* These remarks of necessity can only extend to the motor nerves and the muscles, and we shall neglect the sensory and special nerves, reserving what little is known of them for subsequent consideration.

It may be said, as a general statement, that the electrical irritability of the motor nerves and of the muscles remains quite unaltered, in quantity as well as in quality, in cerebral diseases, especially in paralysis proceeding from the brain.

To this rule there are a number of exceptions, easily defined in themselves, but not very important practically.

A slight *increase of electrical irritability* is sometimes found in cerebral paralysis, chiefly in the apoplectic form, in the period immediately following its occurrence, and apparently after paralysis with contraction; it is generally very slight and soon disappears. Something similar is occasionally found in certain forms of convulsions, which are possibly of cerebral origin, such as chorea minor; it is still doubtful whether tetanus, with its very great increase of irritability, may be reckoned as belonging here.

Qualitative alteration of the galvanic irritability of the nerves has been found a few times in cerebral tumours and other diseases, and, it is said, also in psychoses; it is not of any important diagnostic significance.

Simple diminution of the electrical irritability (without qualitative alteration and reaction of degeneration) occurs sometimes in youth, in the earliest manifestations of hereditary hemiplegia (after encephalitis, hæmorrhage, and the like), in which there is also an arrest in the growth of bone and in the nutrition of muscle.

The reaction of degeneration occurs when the cerebral nerves (facial, trigeminus, hypoglossal and spinal accessory) have sustained a severe lesion at the base of the skull, as in basal tumours, fractures, and the like; in cases in which the nuclei of the motor nerves are diseased, as in the partial degenerative reaction in progressive bulbar paralysis, the complete in tumours of the pons, and the like; or, finally, in very rare cases, where descending secondary degeneration of the pyramids extends to the grey anterior columns of the cord and causes degenerative atrophy in the region of the spinal nerves.

But in the very frequent cerebral paralysis after hæmorrhage or embolism the electrical irritability generally remains quite unaltered, often for years, and no difference can be perceived between the two sides even with the most refined methods of investigation.

I shall now give you a few hints to the treatment of the several forms of disease, without, of course, going into all the details, and these must be modified in practice according to the separate cases; individual differences are so considerable that only a general sketch of the treatment can be given.

Among the *functional disorders of the brain* I have only a few to mention here; I shall treat of the most important ones (chorea, epilepsy, hysteria, paralysis agitans, &c.) specially in subsequent lectures, and shall consider the psychoses separately. *Cerebral neurasthenia* must be discussed in the first place—that frequent form of disease which has lately been described under so many different names, and which is now admitted with certainty into the nosology. Its symptoms are weight in the head, confusion, sleeplessness, want of desire and ability to work, hypochondriacal and depressed feelings, vasomotor disturbances, the various pathological conditions of fear—dyspepsia, palpitation, and many others. It occurs in innumerable variations.

It may be treated *galvanically*, with longitudinal, transverse, and diagonal passage of the current through the head, with weak, stabile currents; the direction may be defined more accurately, according to Löwenfeld—viz. that with symptoms of congestion the anode should be applied in front to the forehead, and with symptoms of anæmia the kathode, &c. It is sometimes also useful to apply both successively; this must be tested in each individual case. A strictly polar method may also be tried, the one pole (a large head electrode) being applied to the vertex and the fore part of the head, the other to the feet for from one to five minutes, the anode or the kathode being placed on the head, according to choice. This procedure may be extended to the employment of the central galvanisation of Beard (vide p. 275). Finally, the galvanisation of the sympathetic and of the cervical cord, according to the well-known methods, is of special service in many cases.

For the *faradic treatment* of the head mild faradisation, by means of the 'faradic hand' or the large electrode, is to be first recommended; best applied longitudinally through the head (anode anteriorly), or by a unipolar application to the head, the other pole being at the feet. This serves as a compromise for general faradisation, which is of decided benefit in many cases. Rumpf appears also to have achieved splendid results in diseases such as these by means of farado-cutaneous brushing, as has also Niermeijer.

Begin in these cases cautiously, with weak currents and short sittings, as the patients are often very irritable and imaginative. If the application is well borne you may proceed to more energetic action, especially with the faradic current. The galvanic sittings should not last longer than from 1½ to 3 or 5 minutes, the faradic up to 5 or 10 minutes; and the sittings may be taken from 3 to 6 times a week. The treatment must generally be continued for a long time.

The *sleeplessness* which plays so great a part with many patients, and which is practically of so much importance, may be treated in exactly the same way. It is a frequent experience, with all electrical practitioners, that by the electrical treatment of the most widely differing parts of the body, but especially of the head and neck, a decided inclination to sleep is often induced, and that restless and disturbed sleep becomes better and deeper, often quite normal. We are thus warranted in subjecting this troublesome symptom to direct electrical treatment, and to this end you may use all the methods which I have just given you for the treatment of cerebral neurasthenia. The results are often quite surprising (vide supra, Obs. 3). The electric bath seems to act very beneficially in many cases, along with general faradisation. Finally, I would also recommend, for many cases, the wearing of a simple galvanic element on the head (vide p. 284 et seq.)

Of the grosser anatomical changes in the brain it is chiefly the *disturbances of circulation*, cerebral hyperæmia and anæmia which become the subjects of electrical treatment.

Löwenfeld's indications may serve as a guide here—longitudinal passage of the galvanic current through the head, in hyperæmia the anode on the forehead, in anæmia the kathode (i.e. more correctly, the kathode in the neighbourhood of the vasomotor centre in the cervical cord in hyperæmia, the anode in anæmia). To this you may add suitable treatment of the cervical sympathetic and the cervical cord. With regard to the sympathetic, it must first be ascertained by experiment whether the application of the kathode to the superior ganglion has a different influence on the circulation from the application of the anode. A moderate faradic current longitudinally through the head can also act upon the circulation in the cranium (Löwenfeld), as will a reflex action from the skin, by means of the faradic brush, with which Rumpf has attained good results in hyperæmia. Would this procedure (with relatively stronger currents) be useful in anæmia also?

But by far the most frequent and the most important object for electrotherapeutics in this connection is *cerebral hæmorrhage*, cerebral apoplexy with its consequent paralysis—hemiplegia or paraplegia, with or without simultaneous anæsthesia, with or without secondary contractions, aphasia or anarthria, asymmetry of the tongue and of the face, implication of the organs of special sense, &c. These very frequent forms were at one time almost the only brain diseases which were treated with electricity; peripherally only in the days of faradisation, and since the introduction of R. Remak's procedure by direct application to the brain and the centre of disease itself.

Before everything else the much-disputed question meets us at what period after the appearance of the hæmorrhage and paralysis the electrical treatment may be begun, and when it *must* be begun. The question has been answered in many different ways; while Remak begins the galvanic treatment of the head very early, one or a few weeks after the coming on of the hæmorrhage, with the intention of using the katalytic action of the current for the more rapid absorption of the extravasation and the prevention of inflammatory reaction, others, from the dread of undesirable irritation and of a return of the bleeding, have urgently recommended that the electrical treatment should not be begun too early, but, at the shortest, six months after the occurrence of the hæmorrhage. The middle course will be found here, as it so often is, the correct one. Nature does the best thing in healing, and we would do well to disturb nature's cure as little as possible, and then to await patiently its development and direction. In any case precaution is necessary at the very first after the bleeding, in order to provide rest for the brain, the vessels, and the irritable heart. On the other hand there is certainly no danger worth mentioning when some caution is exercised in the application of the current. I begin the electrical treatment in such cases after about 3 or 4 weeks, counting from the occurrence of the paralysis; in very slight cases it might be begun sooner, but in more severe cases, in very sensitive individuals, with irritable circulation and extensive disease of the vessels, perhaps not till later. In this also the various cases naturally differ very much.

Special caution is, of course, necessary in all such patients with regard to the relations of the circulation, the existing miliary aneurisms, and the consequent constant danger of renewed hæmorrhage, especially if we have to do with individuals of very advanced years.

Of course, in the direct treatment of cerebral hæmorrhages, the galvanic current alone comes into consideration. The method of its application consists in its conduction longitudinally, transversely, and, if necessary, also diagonally through the head in the manner already specified. As the hæmorrhages occur mostly into the region of the large ganglia of the base and the internal capsule, the transverse passage through the posterior temporal region may be tried first, and also the diagonal passage from there to the nape of the neck; the more the symptoms indicate that the lesion is in the neighbourhood of the cerebral surface (third convolution—aphasia; central convolutions) the more must the other electrode be directed towards that spot (cf. fig. 28, p. 289). It is customary, for the most part, to have the anode on the side of the lesion, with the idea that it is less irritating in its action, and therefore less dangerous; but it seems questionable whether it should not rather be the other way, for it is difficult to decide whether the circulation should be accelerated or retarded in such cases. It may very probably be different in individual cases, and it is, after all, not very important. The duration and frequency of the several applications may be as usual, and you may employ in addition a double-sided galvanisation of the sympathetic, after the recognised manner.

In all old cases, especially those associated with contractions in the paralysed parts (from descending degeneration of the pyramids), you will do well to employ oblique conduction, because by that means the whole motor tract can be influenced as far as the pyramids; and to add to this the treatment of the spinal cord, as I shall describe it to you later on.

Besides this the *peripheral symptomatic treatment* should not be neglected. For the paralysis you should make a labile application of the kathode, with repeated KC (the anode being on the nape of the neck); or you may employ faradisation of the paralysed nerves and muscles. For anæsthesia the same measures may be adopted, or the methods of Vulpian and Rumpf. For contraction you may repeat the experiments of Remak, relaxing the muscles by strong stabile currents, by repeated interruptions, or by very strong faradic currents; or, following Lange, you may have recourse to strong faradisation of the contracted muscles, then passive extension of the same, fixation of the extremity in the condition of extreme extension on a splint, and then gentle faradisation of the most paralysed antagonistic muscles (the extensors). The usual methods may be employed for aphasia, anarthria, possible difficulties of deglutition, hemianopia, deafness, &c. For all these things I refer you to subsequent lectures.

The results of electrical treatment in cerebral hæmorrhage and its sequelæ are so very variable—being sometimes brilliant, but often negative—that accurate statements cannot well be made on the subject; in almost all cases, however, a trial of electricity is justifiable.

For the patches of softening in the brain, caused by thrombosis and embolism, for anæmic necrosis with its usual sequelæ from the apoplectic fit on to hemiplegia with contraction, anæsthesia, aphasia, &c., the same methods are to be employed as in hæmorrhage, all the more so that we are often unable diagnostically to divide with certainty the two forms of apoplexy from each other.

Perhaps we ought to aim here rather at an increase of the blood in the part, the establishment and maintenance of the collateral circulation. In that case the anode should be applied to the neck, in longitudinal conduction through the affected half of the cranium, and on the side of the lesion in transverse conduction. Otherwise you must proceed precisely as in cerebral hæmorrhage.

For the other anatomical lesions of the brain—inflammation, degeneration, atrophy, sclerosis, hydrocephalus, &c.—the electrotherapeutical procedure is in general quite the same.

In the more diffuse forms of disease—chronic meningitis, diffuse peri-encephalitis, multiple sclerosis, hydrocephalus, &c.—the most to be recommended is longitudinal conduction through the skull, or double-sided transverse conduction with very large electrodes (and with repeated changes of polarity, on account of the desired katalytic action), besides the treatment of the sympathetic and the cervical cord. You may also employ experimentally the reflex action from the skin, general faradisation, and central galvanisation.

In distinctly local diseases the applications must of course be made to correspond with the seat of the lesion; and this leads to the symptomatic and peripheral treatment indicated by circumstances.

In such cases, gentlemen, you must not at once lose courage; even in severe organic diseases very unexpected improvement and cure sometimes result. I can myself remember three cases in which severe organic lesions (with papillary congestion, amaurosis, violent headache, vomiting, partial paralysis and convulsions, &c.) were indubitably present, so that the diagnosis of a tumour was made almost with certainty, and yet in which, contrary to all expectation, permanent improvement, and indeed almost a cure, was achieved; and another case of apparently hopelessly severe disease of the brain and the meninges, with serious epileptic attacks, advanced dementia, general and extreme tremor, paresis with muscular tension and increased tendon-reflex of the extremities, &c., in which, by means of a year of mixed treatment (electrical, medical, &c.), an extraordinary improvement in all directions was attained.

Such cases revive sinking courage and perseverance in the treatment, for if the possibility and the tendency to improvement and cure be shown by them the improvement can certainly be furthered by an appropriate electrical treatment.

I would mention here more particularly the *bulbar diseases*, which form, indeed, the transition to the spinal diseases, but belong to the cerebral diseases in respect of electrotherapeutical procedures and on account of the position of the medulla in the skull and its special relations to the cerebral nerves.

The most frequent form, *progressive bulbar paralysis* (progressive muscular atrophy in the region of the motor nuclei of the medulla), must certainly be described as incurable, the pretended cures of this disease related by Benedikt applying to other forms; still even here some relief, an arrest for some time, or at least a slower advance of the disease, can be attained by electrical treatment. But there are many other forms of bulbar disease in which electricity has had favourable—indeed, brilliant—results; I have myself published several such (cf. Obs. 16 and 17), and some of Benedikt's cases belong to this category.

The method of treatment—direct treatment *only* by means of the galvanic current—consists in stabile transverse conduction of the current through the mastoid processes (as it is generally a case of double disease), with changes of polarity; in longitudinal conduction from the forehead to the nape of the neck; or eventually in the already mentioned diagonal conduction, it being only essential that in all cases the medulla shall lie well between the two electrodes. To this you may add galvanisation of the sympathetic and of the cervical cord, ascending and descending, stabile and labile currents through the cervical vertebræ (from the upper dorsal to the occiput). In most cases it is very useful to induce a series of deglutition movements, in the manner already mentioned (p. 122), 10 to 20 in each sitting; and also to effect a peripheral galvanisation and faradisation of the nerve-muscle regions, which principally participate in the paralysis and atrophy (tongue, lips, soft palate, ocular and masticatory muscles, phrenic nerve, &c.)

The treatment of this bulbar disease generally demands weak currents, short sittings, and great perseverance.

In really incurable cerebral diseases you will very seldom be able to give relief by means of the electric current; still you may try in many cases—*experientia docet*—whether you cannot influence separate symptoms—the headache, the sleeplessness, the psychical depression, the anæsthesia and paralysis, the disturbances of vision, the difficulties of deglutition, and the like—by means of the electric current, and so relieve the sufferings of the patient. The modes of procedure which will accomplish these ends may be inferred from what has been already said.

APPENDIX.

ELECTROTHERAPEUTICS OF THE PSYCHOSES.

LECTURE XVIII.

Introduction—Historical Notes—The Labours of Arndt and their Results—Short Review of Cases—Important Actions of the Electric Current—Rules and Methods for the Electric Treatment of the several Forms of the Psychoses—Treatment of the various Symptoms.

We have long been unduly backward with regard to the systematic and extensive employment of the electric current in one group, and that one of the most important, of cerebral diseases. The *psychical* affections have, until now, been subjected to electrical treatment very seldom and in a manner that has been quite insufficient. This is the more striking inasmuch as the best opportunity is given for systematic and scientifically conducted experiments of this nature by the fact of large numbers of such patients being treated in separate institutions, and as *a priori* considerations point with some degree of certainty to the extremely favourable influence of our remedy in many of the disturbances in this department of disease.

The electric current, with its varying therapeutical action, seems, indeed, to be specially calculated to develope favourable results in connection with the psychoses, especially in their preliminary forms and stages, in which we have to do with functional disturbances or with the more minute nutritive molecular changes in the brain, or where our present methods of investigation can discover, at most, some alteration in the circulation. Even in cases where coarser anatomical lesions—the results of chronic inflammation and degeneration—form the basis of the mental disease a good result may be expected from the electric current, based upon the analogy of our other experiences.

This has been recently recognised by various psychologists, and the hope has been expressed that the electric current will become of very far-reaching importance in psychology. But the only one who has occupied himself thoroughly and systematically with this subject is Arndt, who has furnished a series of extensive observations upon it; and it is only the length and somewhat theoretical character of his publication which have prevented them from receiving everywhere their due consideration with the consequent criticism which is so much to be desired (Tigges, v. der Heyden). Beyond Arndt there is not much to be found on the subject, as the history of the older experiments may be read in Arndt's work itself. In the earliest period of galvanism, at the beginning of this century, cures of psychical disturbances were occasionally reported, and during the times of the rotation and induction apparatus electrical treatment found its way into several lunatic asylums and was extensively experimented with ; but the current was employed more often as an instrument of terror and of punishment than as a means of cure ; it proved beneficial in very few cases and directly injurious in many, so that it fell gradually into disuse, although several French writers (such as Teilleux and Auzouy) had reported very good results from the electrical treatment of the insane with contact, voltaic, and faradic currents.

R. Remak's efforts to introduce the treatment of cerebral diseases, and even of psychoses, by means of the galvanic current remained a long time without any effectual influence ; Benedikt alone published, in 1868, some cases of good results from the galvanic current in commencing psychical disturbances, in connection with which he specially directed attention to the subject and repeatedly represented its great importance.

Besides Arndt's works we have only to notice a few clinical publications by Neftel, Jolly, Fr. Fischer, Engelhorn, Buch, J. Kayser, &c. Schüle's new manual, judging from the great experience of the author, will probably do much to promote the use of electricity in insanity, and Tigges has recently published a work rich in isolated facts and in results, but not remarkable for trustworthy conclusions.

We may summarise in the following sentences what Arndt has found out by his numerous and laborious investigations with reference to the chief indications :—

'Only such psychical disturbances as depend on so called functional disorders, on temporary anomalies of nutrition, or on derangements of circulation can be cured by means of the electric current; not those which are the result of deep-seated organic changes, although even in these some benefit may be obtained if the idea of a cure is abandoned and only amelioration is aimed at.

'Electrical treatment is more suitable, therefore, for fresh cases, and not for those which have lasted for years; more for the slighter, vaguer forms than for those which are marked by violence, although even these are not to be quite excluded.

'General and especially severe psychical hyperæsthesia is a contra-indication for the use of the electric current.

'The faradic current acts merely as an excitant, and may be chosen when that effect is wanted; it is specially successful in depression, whether it is primary or in consequence of previous outbreaks of violence. Cutaneous irritation of various portions of the skin is almost the only procedure employed, or now and then also faradisation of the phrenic nerves for the purpose of accelerating the circulation and the oxidation of the blood.

'The galvanic current, on the other hand, has other effects besides that of stimulating—alterative, modifying, soothing, katalytic, &c.—and its sedative and soporific actions are especially evident; it is suitable, therefore, for nearly all the other psychoses which can in any case be treated by electricity. The result, however, is by no means independent of the method employed—the direction of the current, the pole which is applied—but these must often be determined empirically; 'the *descending* current should be used if well-marked irritation be present, especially in the circulation and respiration (on which so many psychical symptoms depend), and the *ascending* current in affections which indicate paralysis of the circulatory system. The descending current, therefore, i.e. the polar action of the anode, seems to be indicated in the preliminary stages of the psychoses, and the ascending current (the polar action of the kathode) in the concluding stages, especially of the graver affections.

'The current, however, should be applied, in mental cases, not so much to the head as to the spinal cord and the medulla, with their important vasomotor, circulatory, and respiratory centres; and subsequently also to the peripheral nerves, if irritation, neuralgia, &c., be present. Galvanisation of the head is not to be absolutely prohibited by this rule, but it is to be reserved for those cases in which a transitory stimulating and soothing effect is desired. (In his later experiments, however, Arndt employs galvanisation of the head regularly.)

'The results are not usually apparent until after long-continued treatment; and the strength of the current must be sufficient, and its duration of a suitable length (from 10 to 30 minutes).'

Schüle has adopted in their essentials these views, which are still in want of various modifications, and has acted upon them in many cases, apparently not without result.

The cases which must determine the method of the electrical treatment of the psychoses are furnished, in the greatest and most important part, by Arndt.

Several cases of simple depression, intense apathy, and want of interest have been cured, some of them in a remarkably short time, by means of peripheral faradisation of the skin and muscles in various parts of the body.

Some cases which presented various psychical disturbances—conditions of depression and of exaltation—have been cured by the predominating or exclusive application of the galvanic current to the cervical cord and the peripheral nerves; cases which have also had in common numerous somatic conditions of irritation—increased sensibility, abnormal sensations, alterations of the pupil, digestive disturbances, constipation, and especially numerous well-marked vasomotor disorders. The stabile action of the anode was of special service here.

In another series of favourably affected cases (against which, certainly, many failures must be set) Arndt has brought even the head, as well as the cervical cord, the sympathetic, the vagus, &c., under the influence of the one pole, generally the anode; while the other pole was applied to some distant part—the sacrum, the thigh, the hand, or the foot. These were cases of very varied psychical character—conditions of exaltation and depression, intense feelings of anxiety, several cases of severe katatonia, primary dementia, hysterical psychoses, reflex psychoses, and the like—but which had all developed from a neuropathic or a psychopathic cause, and mostly showed various symptoms of excitability and irritable weakness in the domain of the vasomotor and circulatory nerves, the vagi and the nerves of respiration, the splanchnics and the genital nerves. The action of the anode shows itself, as a rule, the most beneficial on the central nervous system; but Arndt has met with some cases in which its action proved hurtful, while the kathode had the desired effect. The choice of the method must, therefore, be made with due restriction, and must be modified from time to time according as the result is success or failure.

Benedikt communicates, with his accustomed brevity, a whole series of observations, according to which all kinds of psychical disturbances and symptoms were removed or improved by means of various methods of electrical treatment—general faradisation, galvanisation of the back and of the sympathetic, galvanisation longitudinally through the head, &c. He also lays great weight on the treatment of the back and of the sympathetic, because he sees an important cause of the psychical symptoms in the vasomotor disturbances. Neftel also reports some successful results. M. Buch describes a case of acute primary dementia, with hallucinations, in which the very brief application of a very weak current (two elements) transversely through the temples appeared to be of very evident service.

Franz Fischer saw a case of severe hypochondriacal melancholia, with vivid hallucinations of all the senses, cured in a short time by galvanisation—transversely and longitudinally through the head. The same observer had particularly good results from general faradisation in a case of long-standing melancholia, with demonstrations of violence and decided vasomotor symptoms; after the first sitting there was great improvement for the moment, which continued after the fifteenth sitting and went on to recovery.

Engelhorn also saw excellent results from the same method in two cases (of epileptic and of hysterical insanity), in which great general weakness, exhaustion, poor sleep, &c., were present; and Löwenfeld has influenced some cases of psychical disturbance and sleeplessness in a very beneficial manner by means of general faradisation.

Hitzig, as well as Schüle, states that he has obtained good, if only temporary, results from galvanic treatment of the head, and especially of the nape of the neck, in progressive paralysis. Mendel's results were negative. I have myself also treated galvanically a whole series of cases of commencing paralysis—longitudinally and diagonally through the head, and the sympathetic in the neck—but without attaining thereby striking or even noteworthy results.

J. Kayser reports a large series of cases from Jolly's clinic, treated by electricity, including various forms of disease, mostly among women, in which only negative results were obtained with regard to the principal affection, but where there was some temporary improvement in individual symptoms.

Tigges has seen many beneficial results as to sleep, abnormal sensations in the head, trunk, and limbs, vertigo and precordial anxiety, singing in the ears, tenderness on pressure in various situations, stupor, &c., from electrical applications, especially to the head, back, sympathetic, epigastrium, &c.; but no specific polar action was made out. In a comparatively large number of cases of melancholia, most of them associated with abnormal sensations, the results were very good; v. d. Heyden had such in three cases of comparatively recent melancholia. In melancholia with a moderate degree of stupor the effect was often satisfactory, but in mania, frenzy, or imbecility only very partial or momentary. Still Tigges does not yet draw any more accurate indications from his observations.

In some cases of periodical melancholia I have employed the galvanic current after various methods; it repeatedly appeared to be of use for a certain time, but gave no brilliant results. In one case of long-continued apathy with stupor, which had begun to improve, the improvement, especially in the speech, was very materially hastened by the galvanisation of the head and of the sympathetic.

A general survey of the observations, with regard to the electrotherapeutics of the psychoses, which have been made up to the present time, shows us that the psychoses can, in certain cases, be favourably influenced and sometimes cured by the electric current, even in cases in which all other possible remedies have long been tried in vain; but, in spite of the laborious researches of Arndt, we have by no means attained a sufficient precision and clearness in the indications for treatment, with a corresponding development and establishment of the methods to be employed in the several cases. To this end observations, carried on in a much more systematic manner than hitherto, must be collected.

Closer consideration shows us that the *katalytic action* of the galvanic current is in the first place to be noted. The sum of the actions which we include under this name are calculated to combat energetically the various molecular, nutritive, and other changes, and subsequently even the grosser inflammatory and degenerative disturbances, however little we are able as yet to understand either the disorder or the cure.

In the second place come certainly the *vasomotor effects* of the electric currents, especially of the galvanic; for we know by experience that vasomotor disturbances play a very prominent part in the origin and production of symptoms in many mental diseases. And besides this we may hope to act indirectly, by regulating or altering the supply of blood, upon the nutritive and reactive relations of the central organ. Whether this takes place by a modifying action on the vasomotor centre in the medulla and in the cervical cord (and the most recent experiments of Rieger and v. Forster[1] admit of such a possibility), or by influencing the contents of the vessels in the brain by the direct application of the pole to the skull itself (according to Löwenfeld), under any circumstances we ought to avail ourselves of these powerful actions in particular cases.

The value of the *modifying actions* of the current seems to me to be much less obvious, and I cannot help regarding Arndt's attempt to refer all the effects of the galvanic current to the anelectrotonus or the katelectrotonus of this central nerve-apparatus, and to explain everything by this alone, as extremely premature. I have already been obliged, on general grounds, to declare against this one-sided exaltation of the electrotonic effects for the explanation of therapeutical results (vide Lecture XIII., p. 242); I do the same here with double emphasis with regard to this highest and most complicated part of the nervous system. For what is an anelectrotonus of 'the brain,' of 'the vasomotor centres'? What do we know about it? I would certainly be the last to deny the facts gained by

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[1] Rieger and v. Forster, 'Auge u. Rückenmark,' *Arch. f. Ophthalmol.*, *u.s.w*, Sept. 1881.

Arndt, or to refuse to recognise the different actions of the poles; but let us first content ourselves with the facts, and then seek to increase and to verify them, instead of surrounding them now with such hypothetical explanations, and thereby, perhaps, giving a false direction to the whole investigation. At all events the fact of the different action of the two poles, established by Arndt beyond the possibility of doubt, although apparently, from Tigges's observations, not invariable or regular, is of the very greatest interest and urgently demands further investigation.

Finally, the value of the *exciting actions* of electric currents in insanity is established with regard to the peripheral excitation of the cutaneous and muscular nerves, from which a modifying effect on the function and the circulation of the central organ may be expected; it has still to be accurately determined whether a direct, exciting action on the brain and on the spinal cord, especially the cervical portion, can be of service; probably it can, and a part of the effect described by Arndt as electrotonic may belong to this category.

I have myself too little experience in this wide and difficult department to be able to give suitable rules for the electrical treatment of the psychoses; I shall confine myself, therefore, to short suggestions and hints, which may be of use to those who wish to devote themselves specially to the subject.

In the first place, you will select for your experiments *recent* and *comparatively slight* cases, especially the more vague and ill-defined psychopathic conditions, with morbid dread, sleeplessness, &c., but without any decided fancies. For such cases simple longitudinal (or diagonal) passage of the current through the head, according to Neftel's method, is very suitable, and you may make use of Löwenfeld's directions, given above (vide p. 336); to this you may add the simultaneous galvanisation of the sympathetic, and subsequently of the cervical cord.

If such cases are associated with profound anæmia, general weakness and want of tone, suspended digestion, and the like, a trial may be made of general faradisation, alternating, perhaps, with the galvanic treatment.

In *more severe and fully developed cases*, in pronounced melancholia, in stupor and allied conditions, in dementia, in katatonia, in hysterical and reflex psychoses, &c., you will do best to proceed, according to Arndt's method, with a sufficiently energetic, unipolar action of the galvanic current, increasing in intensity and duration gradually and with caution, to the head, the nape of the neck, the sympathetic, &c., the indifferent pole being applied to the feet and the abdomen. (This is really almost the same as Beard's 'central galvanisation;' vide. p. 270.) The choice of the different electrodes will depend chiefly upon the quality of existing somatic (especially vasomotor, circulatory, and respiratory) disturbances, and upon the character—exaltation or depression—of the psychical anomalies: in well-marked irritative conditions (principally in the preliminary stages) you choose the anode; on the other hand, in decided conditions of depression and torpidity, in vasomotor weakness and paralysis (chiefly, therefore, in the last stages, in secondary melancholia and in melancholia stuporosa, &c.), you use the kathode. But you must never forget that everything depends upon experiment, and that sometimes just that pole which is opposed to your theoretical suppositions will be the effectual one.

It is still questionable whether the results of the *electrical examination* can furnish any data for the therapeutical choice of the different poles; but if an increase of excitability—quantitative elevation, early appearance of ACC, ready production of AOC—be present, the anode may be chosen; if a diminution of excitability, the kathode. There are, certainly, a number of exhaustive experiments (especially those of Benedikt and Tigges) concerning the electrical sensibility of the insane; but they present such a bewildering multiplicity of symptoms, and proceed from a time of such scanty development of the means of testing the quantitative irritability, that definite conclusions cannot be drawn from them.

If the above-mentioned methods do not attain the desired end, others may be tried. In *stupor* and similar conditions, as also in simple depression, the faradic current is very suitable in the form of cutaneous irritation of different spots, or still better in the form of general faradisation.

For *periodic melancholia*, besides the treatment during the attack itself (which will not generally be successful), treatment in the free intervals must also be considered, in order to lengthen those intervals, with a view to prevent the return of an attack. I would most emphatically recommend a trial in this direction. The best method of treatment for this is the galvanisation of the head, and perhaps also the constant wearing of a simple galvanic element on the head (vide p. 285).

In *dementia paralytica*, besides the head and the sympathetic, the cervical cord and the spinal cord as a whole must be treated; Schüle recommends the ascending current for this purpose, but that also must be determined by circumstances. Further than this, you will not attain much in this or any other form of psychosis depending on severe organic lesions.

In conditions of *great excitement*—acute mania, madness, and the like—you will not desire to make any experiments. Any attempt is also contra-indicated in general nervous hyperæsthesia, and especially in psychical hyperæsthesia, where the least effort at electrical treatment throws the patients into the greatest terror and excitement. It should, at all events, only be conducted with the most scrupulous caution.

In many insane patients, however, you may treat *individual symptoms* by themselves; as, for example, *sleeplessness*, according to the method mentioned above (p. 344); further, *hallucinations*, especially those of hearing. If these are connected with galvanic hyperæsthesia of the acoustic nerve the directions to be given later for the galvanic treatment of nervous singing in the ears must be followed. Jolly has seen no special result from this treatment; Erlenmeyer, on the other hand, has had great success with it, and Franz Fischer had one brilliantly successful case of galvanisation of the head in hallucinations of hearing, without hyperæsthesia of the acoustic nerve. Althaus has seen hallucinations of hearing, which had existed for several days, disappear after a single application of galvanism to the 'centre of hearing.'

The *morbid feelings of anxiety* will sometimes be removed by faradisation or galvanisation of the epigastrium and the cardiac regions (see Obs. 3), and the abnormal sensations in the head, back, limbs, &c., cured by suitable local applications.

Anæsthesia, *paresis*, and *atrophy* in the insane will be treated by the methods proper to these symptoms, which will be given later on; *general anæmia*, *dyspepsia*, *wasting*, *con-*

stipation, &c., can be treated and influenced partly by general faradisation, partly by various local electrical applications, of which more will be said subsequently.

It is plain that a wide and remunerative field of labour still lies open here; but it is also plain that only a very systematic and comprehensive mode of procedure can lead to advance in this direction. It is, of course, the lunatic asylums which are specially called upon to undertake the care of this part of the treatment of the insane; but still I would rather be inclined to say that it is the hospitals and homes for nervous diseases, now to be found everywhere, which offer the best field for comprehensive experiments, because it is just in these institutions that the early, slight, vague, curable forms, the premonitory and preliminary stages of the severer psychoses, are gathered together. Suitable early interference here may certainly be able to avert much mischief. Let, therefore, the systematic employment of electricity in psychopathic conditions be urgently impressed upon the physicians of such institutions. But, at the same time, the rule must, of course, be observed that, for the foundation and development of electrotherapeutic methods, only as uncomplicated cases as possible should be chosen.

II. DISEASES OF THE SPINAL CORD.

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LECTURE XIX.

Introduction—Physiological and Theoretical Bases of the Electrotherapeutics of the Spinal Cord—Therapeutical Facts; Selected Cases; Conclusions drawn therefrom—Therapeutical Failures—Spinal Diseases in which good Results may be expected from Electrical Treatment—Technique of the Electrotherapeutics of the Spinal Cord—Direct Treatment: Action of the Poles and of the Direction of the Current—Methods of Application in Circumscript Diseases and in those extending along the Length of the Cord—Indirect Treatment: from the Sympathetic—Combined Sympathetic Treatment—From the Skin: Reflex Influence—Diplegic Excitation—Treatment of the Spots of Tenderness and Pain—Symptomatic Treatment.

In the electrotherapeutics of spinal affections we stand upon firmer ground than in that of cerebral diseases. There is a great deal more experience in this department of disease; spinal affections have for a longer time and more extensively been the subject of electrotherapeutical experiments, and the pathology, as a whole, of the spinal cord has outrun that of the brain in its development.

It is Remak's merit to have taken up and advanced the electrical treatment of spinal diseases with the greatest zeal and energy. The erroneous and generally accepted assertion of distinguished writers, that the spinal cord cannot be affected by currents of a strength which can be employed on men, only hindered and retarded these endeavours for a short time. Even without any experimental contradiction of this error the weight of accumulated facts would have sufficed to establish the striking results of electrical treatment in numerous spinal diseases against the very obstinate scepticism that prevailed. Physicians have since undertaken to combat spinal diseases by means of electric, principally galvanic currents, and records of good, sometimes of brilliant results of this treatment have been given on every side. And while it cannot be denied that a very great, and in some forms of disease even a decidedly preponderating number of failures must be set against these results, that in many cases only very small or partial success can be attained, still the number of positive facts, useful for further conclusions on this subject, is already so great that the electric current has won for itself a secure and prominent place in the therapeutics of chronic spinal diseases. And the whole art of electrotherapeutics depends, in its essentials, on these clinical and therapeutical experiences.

For what we know, by physiological experiment, of the electrical influencing of the spinal cord is extremely scanty, and is in no wise calculated to awaken a prepossession in favour of the therapeutical employment of electric currents, or to give distinct data for the manner of their application. I would refer you to the little that I have communicated to you, in its own place (vide Lect. VII.), about the electrophysiology of the spinal cord, and you will acknowledge that it cannot be enough to furnish us with *a priori* conclusions as to the probable therapeutical value of electric currents in spinal diseases.

But at the same time we are entitled, on the ground of our general knowledge of the action of the current, and on the ground of numerous therapeutical experiments on peripheral nerves and on other organs of the body, to expect decided curative effects on the diseased cord; these are to be established in the same way as we developed the subject in the case of cerebral diseases (Lect. XVI.), although here much more complete and solid experimental bases were at our disposal.

On this principle we might hope for good results, in many cases, from the *katalytic action* of the current on the finer and grosser disturbances of nutrition, on the different forms of inflammation and their sequelæ, on the chronic degenerative processes, on the so called functional diseases of the spinal cord, and the like. The *vasomotor action* of the electric current appeared to be no less valuable in disturbances of circulation, and for the purpose of compensating nutritive disturbances, &c., all the more because recent experiments tend to show with increasing certainty that an influence on the circulation and the amount of blood in the spinal cord as well as in the brain may be attained indirectly, not so much from the vasomotor tract, the sympathetic, as reflexly from the skin. Finally, it was not to be denied that the *exciting and modifying actions* of the electric currents on the spinal cord might be useful in certain conditions—chiefly in functional disturbances, irritation or debility, certain forms of convulsions, certain forms of functional paralysis—however hazy these actions in a physiological sense, and, on the other hand, the essence of the disease in a pathological sense, might be. When all were taken together, most was to be expected *a priori* from the so called katalytic (including the vasomotor) actions (as was first mentioned by Remak); and the methods followed by most observers prove indeed that they reckoned in the first place upon these actions.

All these *a priori* considerations, however, must remain as assumptions so long as their correctness was not confirmed by practical experience; only extensive therapeutical experimentation could decide upon them. But this point has been decided long ago: practical experience exhibits a number of sure and indubitable cures in the various spinal diseases; it has taught us that we can obtain a cure in many cases, and shows the way in which it is possible, some of these ways being such as we should not have foreseen. The following small collection of appropriate observations (which might be amplified very considerably) will furnish you with examples.

18. *Observation by Hitzig. Subacute Spinal Myelomeningitis.*—A sergeant, aged 33 years. Fell with his horse in March 1865; lasting pain in the back ensued. In May 1865 pleurisy and a gastric affection (ulcer?). From July 1865 more important complications: pain in the back, excentric pains in the extremities; general cutaneous hyperæsthesia; formication and numbness of the legs; partial and general muscular twitchings, great disquietude in the legs; diminution of motor power; incontinence of urine. Later on, great uncertainty in walking, especially in the dark, progression possible only in a bent position, because of great pain in the back. Continued bad sleep. Condition in January 1866: Great weakness in gait, bent position in standing, great swaying when the eyes are shut. Pupils normal. Sensibility greatly disordered; deadening of the sense of touch with marked hyperæsthesia; great tenderness on pressure in the spinal column. Treatment hitherto pursued (with arg. nit., iodine, derivatives) unsuccessful. Galvanic treatment with descending stabile currents through the back. After 8 sittings quiet sleep for 7 hours, hardly any more spontaneous pain, feeling of ease in the legs. Further treatment showed that galvanisation of the sympathetic acted specially favourably on the general condition. Later on the crural nerves were treated with descending currents. After 6 weeks of treatment nothing was left of the nervous symptoms except moderate pain on pressure on several intervertebral spaces.

The patient then had to undergo severe military service for 9 months, after which he suffered a relapse, in consequence of overexertion and cold, with a fresh set of well-marked and severe symptoms, from which he was completely freed in from 2 to 3 months by similar galvanic treatment.

19. *Personal Observation. Chronic Spinal Meningitis, or Hyperæmia of Spinal Cord.*—A youth aged 15. Had an illness in February 1870, described as 'inflammation of the brain' (pain in the head, vertigo, vomiting, long-continued unconsciousness). Much pain in the head since; not so healthy as before. Since August 1870 much pain in the small of the back and in the left side; since the end of December 1870 greater weakness in the legs, ready exhaustion, feeling of formication and coldness in them. Upper extremities normal, sleep unquiet; now and then a little vertigo. Condition on January 20, 1871: Several lumbar vertebræ very tender on pressure; movements of the lower extremities possible on exerting sufficient force, but patient becomes tired very quickly; after 10 minutes' walking he cannot go on because of weight and stiffness in the knees and sinking in the legs. No swaying when the eyes are shut. Sensibility normal; reflexes not

increased. Vision defective on account of double leucoma. Hearing good on both sides; frequent singing in the ears for the last few weeks (simple hyperæsthesia of the acoustic nerve on both sides). Galvanic treatment: 12 elements Stöhrer, ascending, from the back to the cervical sympathetic; 16 elements, ascending, through the spinal column, the kathode being moved slowly up and down. February 12, 1871: Extraordinary improvement. Headache and singing in the ears entirely disappeared; no more sacral pain; paræsthesia and weakness of the legs entirely disappeared. On February 18 discharged cured, the abnormal reaction of the acoustic nerve the only remaining symptom.

20. *Personal Observation. Concussion of Spinal Cord* (*Meningeal Apoplexy?*).—A labourer, aged 55, fell from a tree 4 weeks ago on the feet and buttocks, became *immediately lame in the legs*, and had to be carried home. Severe, diffused pain in the sacrum and in the legs. The legs quite lame for about 8 days, after which movements returned gradually, so that a little walking is now possible. Anæsthesia was never present. Micturition quite normal. Pains disappeared gradually. Condition: Distinct *weakness in the legs*, unsteady gait, dragging of the feet, no ataxia. Standing on tiptoe and on one foot difficult. Tremor after long standing. Sensibility normal. Skin and tendon reflexes normal; no distinct atrophy; *electrical irritability simply lowered.* Sphincters and upper extremities normal. No alteration in the back or the spinal column. Treatment: *Galvanisation of the spine and of the legs.* Striking result. After a few sittings patient could walk well, and after 22 daily sittings he was discharged cured.

21. *Observation by Lewin. Complete Paraplegia* (*in consequence of Acute Myelitis?*) *Cure by means of the Galvanic Current.*—A woman, aged 35; not hysterical. Ill for about 3 weeks with fever, weakness and numbness of both legs, slight dragging pains; after 8 days suddenly *complete paralysis of the legs, severe lancinating pains, girdle-feeling, paralysis of the sphincters.* Reflexes normal. Sensibility not markedly disordered. Treatment with descending stabile currents. After 5 days pains ceased; left leg can be raised a little. After 14 days paralysis of the sphincters disappeared. After 4 weeks patient can raise both legs and stand for a few minutes; the fever has abated. After 7 weeks patient can walk through the room easily, but a little awkwardly, &c.

22. *Personal Observation. Traumatic Paraplegia.*—A soldier, aged 23. Received a gunshot wound in the cervical part of the spine at Wörth (August 6, 1870). The ball passed from the middle

of the left sternomastoid to the posterior part of the right spine of the scapula—probably through the spinal column. Immediately afterwards *complete paralysis and anæsthesia of the legs, extending upwards to the thorax*; retention, subsequently incontinence, of urine, which disappeared again after 4 weeks. Sensibility and motility improved gradually, especially in the left leg; the wound healed without complication. Condition on October 20, 1870: The 6th and 7th cervical vertebræ somewhat tender on pressure. Sensibility comparatively restored, only somewhat diminished subjectively still; all movements in the left leg carried out, but with little force or certainty; the right leg, on the other hand, extremely paretic; only traces of movement in the foot and toes; frequent clonic trembling in the legs, especially in the right. Arms free. Bowels and bladder act well. Electrical irritability well preserved in the lower extremities. Galvanic treatment: Stabile currents through the back, with special regard to the wounded spot; then A in the nape of the neck, and K labile through the nerves of the legs. (Patient must be carried to the treatment.) Improvement progressed very rapidly: after the 7th sitting the patient can stand a little on the left leg, and can move the right one more easily and extensively. After the 10th sitting he can walk round his bed; after the 12th he can stand alone and take a few steps; after the 16th he can walk alone to the treatment, only supported by a stick. After 40 sittings he walks quite nimbly with a stick, the right leg being dragged a little still.

23. *Observation by Seeligmüller. Myelopathy. Tabes Dorsalis?*—A mason, aged 42. Two years ago the second attack of a 'paralysis,' which affects him still. Gait uncertain, staggering, only possible with the help of a stick; dragging of the left leg, weakness in the right arm; great swaying when the eyes are shut. Getting up on a chair impossible. Pains in the back of the neck and in the sacrum, paræsthesia of the hands and feet, girdle-feeling, anæsthesia of the hands and an anæsthetic zone at the back of the neck, from the spine of the scapula to the vertex. Impotence, weakness of the bladder, constipation. Galvanic treatment: 10 elements, descending, through the cord (from the neck to the loins) daily for 10 minutes. Surprising result: even after the first sitting the pain less, sensibility improved; patient can walk on the street without a stick for the first time for a lengthened period. After the 5th sitting gait manifestly improved, feeling of weariness disappeared. Sleep good; sensibility nearly restored again. After 14 sittings patient discharged cured; can carry on his trade as mason and lamp-lighter. This improvement has continued for a year and a half.

24. *Observation by v. Krafft-Ebing. Tabes Dorsalis.*—A butcher, aged 26. Ill for a year; paræsthesia and numbness of the legs, with weakness and increasing uncertainty; darting and boring pains in the lower extremities; uncertainty in the dark, in going upstairs, and in turning; walking increasingly difficult and only possible with a stick. Bladder and rectum normal. Hydropathy and nitrate of silver have had no effect to speak of. Very great ataxia of the lower extremities; rough strength good; can only walk for 5 minutes with the aid of a stick. Great swaying when the eyes are shut. Swaying gait; lancinating pains; circumscript anæsthesia, principally in the right leg and foot. Galvanic treatment: Stabile current along the spinal column daily for a few minutes, labile irritation of the peroneal. Distinct improvement even after the 4th sitting. After 5 weeks the treatment had to be broken off. Improvement very marked: sensory disturbances quite disappeared; no more swaying when the eyes are shut; power, certainty, and endurance of the legs restored. Patient can walk for one or two hours, and can resume his arduous calling as a butcher.

25. *Personal Observation. Tabes Dorsalis.*—A tailor, aged 33. Has formerly had a chancre; for 8 years typical lancinating pains; irritative weakness of the sexual organs; trembling in the legs; weakness, uncertainty, and swinging of the legs for 3 years; paræsthesiæ. Rapid and marked impairment 3 or 4 months ago. Great uncertainty in the dark; no double vision. Present condition: Very great ataxia of the legs; can walk only when led and cannot stand alone; gross strength somewhat diminished. Cutaneous sensibility of the legs markedly diminished; pronounced retardation of the conduction of pain with persistence of the sensation. Muscular sensibility greatly diminished; falling when the eyes are closed inevitable. Cutaneous reflexes weak; tendon reflexes absent. Weakness of the bladder; impotence. Upper extremities, brain, and cerebral nerves normal. Electrical irritability in the peroneal nerves simply lowered, in the ulnars a qualitative anomaly in the law of contraction—ACC $>$ KCC (vide p. 214). Galvanic treatment: 12 elements, ascending, from the back to the sympathetic, with reversal of the position of the anode, and 18 elements, ascending, through the cord, with changes of position of the kathode, daily; every 2 days in addition, the kathode labile and descending through the nerves of the legs. (Nitrate of silver at the same time.) Even after 8 days the patient felt himself easier in the legs and had more certainty in walking. After 4 weeks walking was much improved and the lancinating pains much less. After 6 weeks he could walk alone with a stick.

After 8 weeks he could go up and down stairs alone, and the sensibility was improved even objectively. After 12 weeks the improvement had gone on still further and the treatment was interrupted. After 6 months the improvement was still as it was before, but there was no sign of cure. The patient could walk alone, without a stick, and very quickly, but still with some ataxia; he could stand with his eyes shut, but the disturbances of sensibility could still be demonstrated to a small extent and the tendon reactions were still absent.

26. *Personal Observation. Tabes Dorsalis Incipiens* (?). *Atrophy of the Optic Nerves.*—A woman, aged 37. Suffering for some months from decrease in the power of vision, which gradually attained to a very marked degree; at the same time rending pains, formication and numbness in the legs, rapid exhaustion on standing or walking, especially in the right leg, causing some limping. For the same time also continually cold in the feet. Sphincters normal. Condition in January 1874: Marked amblyopia; fingers can be counted by each eye at a distance of from 12 to 16 feet; blindness for red colour, diminution of the field of vision, with the angles on both sides directed inwards. Ophthalmoscopic examination shows atrophy of the optic nerves. Weakness in the legs, swaying gait, some dragging of the right foot; standing on the left foot easy, on the right difficult. The separate movements also somewhat weaker on the right side than on the left. No swaying on closure of the eyes. Local anæsthesia on the dorsum of the right foot and in the toes, sensibility otherwise normal. Upper extremities, brain, &c., normal. Simple lowering of the electrical excitability in the peroneal nerve. Galvanic treatment: 14 elements from the back to the sympathetic, on both sides; and 18 elements, ascending, stabile and labile through the cord. 8 elements stabile from the nape of the neck to the closed eyelids. After 10 sittings considerable improvement; pain much less, sensibility distinctly improved, patient walks more surely, the feet are warm again. After 30 sittings very marked improvement; patient can go up 2 steps without any difficulty, and can walk more easily, quickly and surely; the power of the right leg is also objectively increased; pain and formication entirely disappeared; no apparent objective disorders of sensibility. Even the eyes are somewhat better; fingers counted from 16 to 18 feet off; Jäger No. 7 read with convex glasses. After the 45th sitting, June 1874, persistent improvement; walking and going upstairs quite easy; no more pain or numbness in the legs; feet no longer cold; sensibility objectively quite normal; the eyes also improving slowly. Snellen No. 200 (A) recognised at

20 feet; Jäger No. 7 read with convex glasses. Ophthalmoscopic appearances the same.

27. *Observation by Moritz Meyer. Tabes Dorsalis. Treatment of the Painful Points in the Spine.*—A lithographer, aged 41. Suffers from ataxia; cannot stand or walk without support, has paresis of the bladder and rectum, paræsthesiæ and diminution of localising power in both legs and soles of the feet, disordered sensibility in the ulnar nerves, lancinating pains in the legs and tenderness on pressure on the 4th, 5th, and 6th dorsal vertebræ. Galvanic treatment of the painful spots with the anode stabile had the result that the patient could again walk about the town for hours without inconvenience. Two years later a relapse, with the same symptoms, following a chill. The same good results from the same treatment, although not so quickly; nor was the improvement so complete, a certain number of symptoms remained behind, although the patient recovered his motor powers completely.

28. *Observation by Drissen (communicated by Moritz Meyer). Tabes Dorsalis. Treatment of a Point Tender on Pressure.*—A gentleman, aged 52, who had suffered for 6 years from lancinating pains, and, after a chill caught subsequently, from ataxia in an increasing degree. Gait very insecure; standing very difficult, falling when the eyes were shut; anæsthesia of the soles of the feet, especially the right. The first lumbar vertebra tender on pressure. Treatment: Application of the anode to this vertebra, the kathode alternately right and left on the hip-bone. After the 5th sitting the swaying on closure of the eyes hardly perceptible, the numbness of the soles of the feet gone. The patient, able to walk a long way without a stick and without fatigue, considered himself quite well and left the place.

29. *Observation by Brenner. Tabes Dorsalis. Treatment of the Painful Spots on the Spine.*—A market assistant, aged 42. Well-marked tabes for a year; syphilis formerly. After premonitory double vision, moderate lancinating pains, fatigue and unsteadiness of the legs, weakness of the bladder, &c., distinct ataxia came on, with analgesia, absence of the tendon reflexes, &c. Intense girdle pains developed themselves in two places, the upper one for a hand's-breadth on each side of the chest, the lower on the abdomen, above and below the umbilicus. Galvanic examination with the kathode showed an intensely painful spot corresponding to the dorsal vertebræ from the second to the fifth, and a second on the level of the first three lumbar vertebræ. After two weeks of treatment (with the anode stabile) the upper painful point had quite disappeared, and with it the thoracic girdle pains, and after three weeks more the lower painful spot was

much improved. Simultaneous peripheral (faradic) treatment produced marked improvement on the other tabetic symptoms. (Since that time the patient, who has continued under my own observation, has shown no increase of his disease.)

30. *Observation by Moritz Meyer. Disease of the Spinal Cord (Tabes?). Treatment with the Faradic Brush.*—A literary man, aged 54. Suffered for many years from weakness in the limbs, intense periodic headache, and sensitive pains in the back and in the extremities; the hands and feet had almost refused their work, when, almost suddenly, complete insensibility of the legs and bladder complications set in. The patient could not stand well, or walk without support. Marked swaying when the eyes were shut; girdle pains, intense tearing pains in the upper and lower extremities with partial anæsthesia, incontinence of urine, coldness of the feet. Treatment: Application of the faradic brush to the extremities with a distinctly perceptible current. Great improvement after 3 sittings. After 20 sittings treatment ceased; the patient could walk long distances and use his hands for writing, and the pains were much less severe. The improvement still continued a year later.

31. *Observation by Rumpf. Tabes Dorsalis. Treatment with the Faradic Brush.*—A labourer, aged 40. Never had syphilis, had worked a great deal in wet sand. In the course of 11 years, during which lancinating pains had been present, his powers had gradually diminished: first a severe gastric affection (*crise gastrique?*), then great weakness in the legs, with abnormal sensations in the feet and hands, girdle pains, weakness of the bladder, and, finally, such an increase in the difficulties that the patient could only walk short distances with great trouble and with the help of a stick. Objectively there was undoubted ataxia of the upper and lower extremities with retained motor power, analgesia of the whole surface of the body, diminution of the sense of touch and of temperature, impairment of sensory localisation, intense feeling of fatigue, girdle pains and bladder weakness, absence of all the tendon reflexes. No swaying on closure of the eyes. Argyll-Robertson pupil not present.

Treatment with the faradic brush: Anode on the sternum, the brush being passed over the back and then over the extremities twice for about 10 minutes every other day. After the fifth brushing the pains almost disappeared, girdle pains less, sensibility improved. After 4 weeks marked improvement in all directions, weariness and uncertainty of the legs alone remaining. Galvanisation of the back, alternating with the faradic brushing, was now had recourse to, and after 5 weeks longer the patient was discharged, well and able to work. The only objective symptoms were the absence of the tendon and plantar reflexes and the impairment of the sensory localisation. At the end of one year the improvement still continued; the patellar reflex was still absent, but the tendon reflex in the upper extremity and the plantar reflex had returned.

32. *Personal Observation. Spastic Spinal Paralysis. (Myelitis Dorsalis chronica?).*—A woman, aged 30. Ill for 5 years: weakness of the legs, with subjective coldness and numbness, never any pain; gradually getting worse, and lately with weakness of the arms superadded; inability to stand or to walk absolute for the last half-year. Sphincters normal. Condition: Both lower extremities paretic in a high degree; movements slow and uncertain. The legs at the same time in a certain rigidity; very great tension of the muscles and contractions on passive movements; increase of the tendon reflexes (foot clonus). Sensibility hardly disturbed; formication present; sense of touch, pain, and space objectively normal; only in one or two places an insignificant diminution of the sense of temperature. Cutaneous reflexes somewhat increased; bladder normal. Upper extremities not markedly affected; head and cerebral nerves quite normal.

Galvanic treatment of the cord, including the cervical sympathetic. Surprising result; even after 5 weeks considerable improvement; legs easier and more supple, movements quicker and stronger, muscular rigidity almost disappeared. Gait still awkward and stiff. After 2 months more the improvement still continued to advance, although more slowly. Sensibility normal; motility much better, although not yet quite as it should be; the patient still feels very weak, but can walk across a room and go upstairs alone. Some amount of muscular rigidity and ankle clonus still present. Discharged.

33. *Personal Observation. Poliomyelitis anterior subacuta.*—A stove-maker, aged 47. Had suffered a long time from a feeling of fatigue in the legs. Fell ill in the beginning of October 1878 with slight feverishness and a feeling of weight and moderate pain in the lower extremities; on the following day great weakness, so that he had to walk very slowly; the day after he collapsed on going out, and in the course of 8 or 10 weeks the weakness had increased to complete paralysis of the legs, which lasted for about a week; then some movements began gradually to return. The pain at the same time became more severe, to disappear again with the improvement in the paralysis; there was, however, no paræsthesia, no disturbance of sensibility. No convulsions; bladder normal. Some numbness in the hands and a little pain in the arms. Condition in the end of

November 1878 : Head and cerebral nerves quite unaffected, as also the muscles of the neck and shoulders. Upper extremities normal in motility and sensibility, only a little sinking in of the first interosseous space. Tendon reflexes present on both sides. Abdominal muscles normal. In the lower extremities marked paresis of the whole crural region on both sides, the adductors and the tibial region also paretic, the region supplied by the peroneal nerve alone showing no paresis. Sensibility of the lower extremities entirely normal in every respect. Cutaneous reflexes present; tendon reflexes absent, except a trace of patellar reflex on the left side. The paretic muscles all atrophic to a greater or less extent, and all very tender and painful on pressure and on percussion, especially the crural region and the calf. Electrical examination shows degenerative reaction everywhere, either complete or partial, as well as in the peroneal region on both sides. Galvanic treatment : 20 elements ascending or descending through the cord, especially over the lumbar enlargement, and from 24 to 26 elements, with kathode labile and with reversal of the current, to the nerves and muscles of the legs. Considerable improvement even after 6 days: patient could walk without a stick. After 10 days patient was out of bed and walking about the room, feeling stronger; the muscles of the legs firmer, and no longer so painful on pressure. Marked improvement after 4 weeks, but the reaction of degeneration was still present, and the tendon reflexes still absent. Pause in the treatment, which was resumed after 4 weeks. The improvement went on during that time, and on February 6, 1879, the patient was discharged almost cured. The motility was excellent; the RD was still distinctly perceptible only in the peroneal region, but the tendon reflexes were still absent. The circumference of the legs had greatly increased. The further progress of the case was to complete cure and ability to work.

34. *Personal Observation. Chronic Anterior Poliomyelitis (Middle Form).*—An engine-driver, aged 36. Fell ill in February 1877 with pains in the left arm and diminution of its strength and its size. In the end of August the same symptoms came on in the left lower extremity, and in the middle of November in the right also—deep-seated pains, weakness, and wasting. Sphincters quite normal. Condition in the end of November 1877 : Pronounced paresis of both legs; no ataxia or swaying on closure of the eyes. Sensibility normal in all directions. Muscles very tender on pressure. Cutaneous reflex weak, tendon reflex very well marked. Muscles of the trunk and of the right upper extremity normal. Left upper extremity paretic and wasted, its sensibility normal, its muscles tender on pressure. Tendon re-

flexes intense. Brain and cerebral nerves, spinal column, bladder, &c., normal. Distinct atrophy of both legs; no fibrillary contractions. Electrical examination shows partial RD very well marked, especially in the legs and in the radial region of the left upper extremity. Treatment: Stabile galvanic currents *only to the cord*. Distinct improvement even after the third sitting: intermission of pain, return of power, improvement in nutrition of muscles. Improvement continued to advance, the weakness disappeared, the RD receded gradually, the muscles became firmer and larger, and by the end of March 1878 the patient could be regarded as nearly cured.

35. *Personal Observation. Progressive Muscular Atrophy* (*Spinal Form*).—A brewer, aged 26, without any hereditary taint, noticed slight weakness in the right hand since the winter of 1872–73, combined with formication and occasional twitching in the small muscles of the hand; a little functional weakness also in right shoulder and a gradual wasting of the interosseous spaces in the right hand (especially the first); these disturbances progressing very slowly. For a year and a half the same also in the left hand—weakness, fibrillary contractions, and wasting of the interosseous spaces. Lately also a certain amount of weakness in the legs, especially the right. Otherwise healthy; no syphilis or any other apparent cause for the disease. Condition on May 1, 1879: Slight claw-hand on right side, interosseous spaces deeply sunk; atrophy of the hypothenar muscles and, in a much less degree, of the thenar also. Movements of the fingers limited and awkward; the interossei, however, not completely paralysed. Right forearm markedly wasted in its lower third; much fibrillary twitching, especially in the extensors. Muscles of the upper arm somewhat weak, also with much fibrillary twitching, especially in the triceps. Deltoid still completely unaffected. The left upper extremity presented the same symptoms, but in a somewhat less degree. Dynamometer: right, 13°; left, 19°. Sensibility quite normal. No abnormality in the legs. Atrophy of individual muscles of the back —trapezius, latissimus dorsi, sacrolumbalis—otherwise all normal. Electrical examination showed partial RD very much pronounced in the atrophic muscles of the hand.

Galvanic treatment: Galvanisation of the sympathetic, then A stabile on the cervical and lumbar enlargements, and afterwards K stabile on the same parts. Then A on the back of the neck, and K labile through the nerves and muscles of the upper extremities, especially of the forearm and hand. On May 15 dynamometer: right, 14°; left, 19°. On June 7, after 26 sittings, a decided improvement: dynamometer, right, 19°; left, 33°. The arms decidedly stronger;

patient can do more with his hands than before, and has more skill and strength in them. The paræsthesiæ in the arms disappeared. Discharged, to continue treatment at home.

It would be easy to increase the number of such observations very considerably; but these examples will be sufficient. In choosing them I was guided by the wish to select cases in which electricity had undoubtedly had a rapid and a more or less satisfactory result, and in which it had been employed exclusively or nearly so. It would be particularly easy to accumulate cases in which electricity has been successful only after lengthened and repeated applications, perhaps combined or alternating with other courses of treatment, as in severe chronic diseases of the cord—tabes, chronic myelitis, spastic spinal paralysis, spinal infantile paralysis, &c.—and in cases of protracted and obstinate neurastheniæ. But such cases cannot be used as material for argument, and do not, in the end, teach more than the others; they can only serve as a somewhat broader basis for what has to be subsequently said about the separate diseases.

It cannot, of course, be concealed that the electrotherapeutics of spinal diseases presents an extraordinarily large number of failures, many more than of successes, and a great many more than is to be desired in the interests of the patients. But this is to be expected from the nature of the diseases concerned, though it must not cause us to despair of our therapeutical endeavours.

The observations given above, as well as all the experiments which have, up to the present time, been made on this subject, teach us that a beneficial action from electric currents, in many classes of spinal diseases, is possible, and has been firmly established by unequivocal testimony. And that is a very important result when contrasted with the hopelessness of the former treatment in a great part of these diseases.

You will further learn that this beneficial action may be expected, first, in *simple functional disorders* of the cord—in neurasthenia, spinal irritation, concussion of the spinal cord, perhaps in acute ascending paralysis, &c.—and that here, just as in the case of the brain, the exciting and modifying actions of the electric currents are first to be thought of; though perhaps their vasomotor and katalytic actions may possibly play a still greater part, as they help to remove the supposed more minute disorders of nutrition.

Also in *circulatory disorders* of the cord (hyperæmias, anæmias, increased transudation) it is at least probable that, as in the brain, good effect may be attained by means of direct or indirect action, and especially by reflex action from the skin, but it does not seem practicable to particularise these effects more exactly at the present time. The experiments of Löwenfeld, who claims to have obtained dilatation of the vessels of the spinal pia mater by the descending current (A in the nape) and contraction by the ascending current (K in the nape), are surrounded by too many difficulties, and have not been tested with sufficient accuracy to form a firm basis for therapeutical treatment, especially as in most pathological cases we do not exactly know which condition of the spinal vessels is the more desirable to induce. The vasomotor and katalytic actions of the current may also be valuable in the sequelæ of hæmorrhage or softening of the cord.

Finally, the same beneficial result may be expected in all kinds of *obvious disorders of nutrition* and *grosser anatomical changes*—such as the sequelæ of acute meningitis and myelitis, the chronic forms of these inflammations, myelitis from compression, sclerosis, grey degeneration, atrophy, &c.—and here we have to fall back upon the oft-mentioned katalytic action, which we have so often seen exerted on the external parts. The influences of the electric current on circulation, tissue metamorphosis, nutrition, circulation of lymph, and the stimulation of trophic centres and tracts may certainly accomplish much here which could not always be predicted with certainty beforehand.

We must certainly acknowledge to ourselves (and the many failures of the electrical treatment teach us so in a most emphatic manner) that there are many forms of disease and many cases in which we can expect nothing from electrotherapeutics or from any other remedy, as when there are long-standing and far advanced chronic inflammatory and degenerative changes, in cases of severe contusions and hæmorrhages, with their sequelæ, and similar conditions.

There are many ways and methods of attaining the various therapeutical ends desired. We can treat the cord *directly*, or seek to influence it in an *indirect* manner, from certain vasomotor (and trophic ?) nervous tracts, or reflexly from the skin, just as we do in the case of the brain.

The galvanic current is to be used chiefly and almost exclusively for the direct treatment of the cord; in most cases the vasomotor and katalytic actions have to be taken into consideration, and for such the galvanic current is far superior to the faradic, irrespective of the fact that it penetrates more easily to the required depths than the faradic. The faradic current has, indeed, for a long time taken quite a subordinate place in the treatment of spinal diseases, and only further experience can decide whether Löwenfeld's recent recommendation of it for the direct treatment of the spinal cord, especially in functional disorders, is warranted.

For most of the effects required here, especially for the katalytic and vasomotor, but not less for the stimulating and modifying, it is the first and indispensable condition that the current should be allowed to act on the diseased part with a sufficient strength, density, and duration. This condition must, therefore, determine in the first instance the method of the application.

It is still doubtful in how far the action of the separate poles influences the result of the application; both poles are very much of equal value for the katalytic actions, varying perhaps only quantitatively, and the same may be said of the vasomotor actions; for stimulating and especially for modifying effects, on the other hand, the choice of the pole for the diseased part is certainly not indifferent; it must be determined according to the general rules, but must be tested experimentally in each individual case.

We know still less certainly whether the *direction of the current* plays any part in the treatment of the spinal cord; it is very probably quite indifferent for the katalytic and vasomotor actions, although the experiments of Löwenfeld imply that ascending and descending currents in the cord have a different effect on the contents of the vessels; Löwenfeld is inclined to ascribe this fact to the varying action of the two poles on the vasomotor centres in the cervical cord. The choice of the individual pole is certainly the principal thing in the stimulating and modifying effects, and the direction of the current a secondary matter. However, it is perhaps not indifferent what relative position the two poles bear to each other on the cord —which section of the cord is influenced by the kathode and which by the anode at the particular time—and in this sense the direction of the current may be of some importance. Therapeutical experience alone can decide this question finally, and although a conclusion is not yet nearly arrived at still most electricians are inclined to give the preference to one direction or another in the treatment of certain forms of disease. Thus I prefer the ascending current in spinal weakness, chronic degenerative processes, &c., and the descending only in more irritative conditions; but both directions may be employed alternately in order to influence the spinal cord as intensely as possible.

Having regard to these rules, the *method of application* in the different cases becomes evident: the chief condition is a permeation of the spinal cord by the current, as complete and as intense as possible, to which end the deep position of the organ demands tolerably strong currents. You choose, therefore, large electrodes, and place them as far apart as possible, so that the current may penetrate properly through the tissues (cf. the previous explanation, Lect. IV., p. 60). The use of small electrodes is to be avoided, and it is also wrong to place them very near each other (e.g. on each side of the spinous processes on the same level, as many physicians do); by that means the dorsal muscles and the vertebral processes are galvanised, but not the spinal cord. I generally use my 'large electrodes' (60 to 100 sq. centimetres in diameter), and for very stout patients the 'very large' size.[1] The application must be made as much as possible with the whole surface. If the spinous processes of the vertebræ are very prominent the disks must be directed somewhat to the side, and in that case it is best to place one to the left and the other to the right of the spinous processes. Seeligmüller has tried to get over this, which is sometimes a great disadvantage in very thin patients, by constructing a special electrode in the form of two parallel metal bars, rounded and covered with sponge, between which the spinous processes lie when it is applied. You will always manage quite well, however, even without this electrode.

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[1] V. Ziemssen recommends very long, slightly curved plates, which cover nearly the whole back, and of course admit of a complete penetration of the cord by the current.

It is important, for obvious reasons, to expose the diseased part as directly as possible to the action of the pole—to place it under the electrode in its whole extent. You will choose the one pole or the other according to the conditions of things, and in most cases, especially when a katalytic action is desired, you will do well to let both poles act successively on the diseased part.

The more particular method of application must, of course, be determined by the anatomical relations of the individual case; and here it is allowable to make a distinction between the longitudinal diseases of the cord (systematic degeneration and the like) and circumscribed diseases (foci of disease with very limited longitudinal extension, transverse myelitis, spinal infantile paralysis, spinal apoplexy, &c.)

For *circumscript diseases* it is best to cover the diseased part entirely with one electrode, and to apply the other to the anterior surface of the trunk exactly opposite, so that the diseased part may fall in the course of the line connecting the two. In this way the passage of the current may be most thoroughly secured. As these diseased spots occur generally in the enlargements of the cord you must consider specially the relative position of the enlargements to the different sections of the spinal column in applying the electrodes (vide p. 30). According to indication or inclination you will choose the one pole or the other for application to the back, or you may let both successively act in this manner.

If you are of the opinion that such a purely transverse current is not so effectual you may allow the one pole to remain over the diseased part, and place the other either above or below on the spine, as far away as possible; or you may, in certain circumstances, include the diseased spot between the two electrodes, placed upon the back, not too far from each other. I have often carried out the latter method in myelitis from compression, with very prominent kyphosis, by placing the one pole above and the other below the kyphosis, and so bringing the disease almost directly into the region of densest current diffusion.

In *longitudinal diseases* (tabes, pyramidal sclerosis, multiple sclerosis, secondary degeneration, &c.) you will do best to apply both poles to the back, the one on the nape of the neck and the other in the lumbar region. A stabile action is generally desirable ; but the points of application must of course be varied, in order to bring, if possible, the whole extent of the diseased parts under the influence of the densest current diffusion. Thus you fix the lower pole for example, and let the upper one come gradually downwards over the whole length of the cord (3 or 4 moves are usually sufficient); then you do the same with the lower pole upwards, the upper one being fixed. You can also get the same effect if you fix the one pole on the anterior surface of the trunk (sternum or epigastrium) and let the other act stabile upon the whole length of the spine successively; and this may be done with both poles consecutively.

The determination of which pole shall be allowed to act, chiefly or exclusively, on the diseased spot in these different forms of spinal disease must depend on the peculiarities of the individual case, on the indications to be fulfilled, on the views of the practitioner, and especially on therapeutical experience. Rather uncertain rules are all that can yet be given for the choice of the poles: thus it is customary to prefer the anode in cases of irritation, in recent active morbid processes, in very irritable and sensitive patients; and the kathode where symptoms of paralysis or weakness predominate, in older and more torpid morbid processes (grey degeneration, sclerosis, &c.) and in less irritable patients. At the same time, whenever katalytic effects are principally desired, both poles should be employed successively.

You must at first be extremely cautious about the *intensity* and the *duration* of the application. Choose weak currents at first, and work only with a galvanometer in the circuit (5 to 20 ma. or 20° to 45° N defl. with 150 ohms are generally sufficient). The duration of the single applications must not at first exceed one or two minutes, so that the whole sitting may not last longer than from 4 to 8 minutes. If you see that the current is well borne you may increase the time slowly. But it often happens that too prolonged sittings with too strong currents act unfavourably rather than beneficially, leaving behind them a feeling of fatigue and heaviness, increased pain and paræsthesiæ, disturbed sleep, &c.; you must seek to avoid this as much as possible. The cases for prolonged applications must always be chosen with the greatest care. For the frequency of the sittings and the duration of the whole course of treatment the general rules are applicable (Lect. XV.)

For the *indirect treatment* of the spinal cord the so called *indirect katalysis* of Remak comes under consideration; i.e. the action on those vasomotor (and trophic) nerve tracts which have a special influence on the circulation and nutritive processes in the cord. To this end the cervical sympathetic has always been acted upon, although Remak has now and then acted also on the thoracic and abdominal ganglia. It is certainly difficult to say what justification there is for this, as we recognise in the sympathetic only some fibres proceeding from the spinal cord. Still the plexuses of the vertebral and spinal arteries, coming from the sympathetic, may be of some influence here; and so may the vasomotor tracts for the intercostal arteries. Besides, experience seems to teach that treatment of the sympathetic is not without advantage in certain spinal affections (Flies); and this may specially be the case in those affections which extend into the cervical section of the cord, implicating the pupils, the cerebral nerves, and the brain itself (e.g. tabes). I have, therefore, frequently employed a method of spinal treatment which produces a simultaneous effect on the cervical sympathetic; the kathode ('medium' electrode) is fixed over the superior ganglion on one side, and the 'large' anode on the opposite side of the spine, close to the spinous processes, applied first stabile to the lower cervical and upper dorsal vertebræ, then gradually proceeding downwards by steps, resting a little time on each place; 3 or 4 successive places will be enough, and the same procedure is then repeated on the other side, 1 to 1½ minute being enough for each side. I then generally let the kathode act stabile on the spinal column, applied successively to various points, the anode being fixed over the lower lumbar vertebræ (also for 1 to 1½ minute). It is possible that this procedure may act beneficially only because a better penetration of the cord by the current is attained by the placing of one electrode on the anterior surface of the neck; in any case I believe I have often employed it with advantage. Of course you may also employ the ordinary galvanisation of the sympathetic as well as the ordinary galvanisation of the cord.

Another manner in which to influence the cord indirectly is *reflex stimulation from the skin* by means of irritation of the cutaneous nerves; it is quite beyond a doubt that we can influence the spinal cord by this means, either by inducing a direct, modifying action on the nerve elements themselves, as in functional disturbances, minute nutritive disorders, &c., or by an action on the vessels, just as we do in the case of the brain (Rumpf). But only accumulated experience can show what the truth is about this point.

You can get such a reflex action either by means of 'general faradisation' (and this is specially recommended by Löwenfeld) or, according to Rumpf, by means of the application of the faradic brush to the greater part of the cutaneous surface of the trunk and extremities, as follows: the anode being fixed on the sternum, the back and the different extremities are to be stroked with the faradic brush until considerable redness is produced, this to be repeated twice, and the whole sitting to last for 10 minutes, the strength of the current being such as to be decidedly felt, about midway between that necessary for the minimum of sensation and farado-cutaneous pain. Here also great caution and a gradual increase of the current are demanded.

We cannot for the present decide whether the so called *diplegic excitation*, carried out by Remak and much vaunted in certain spinal affections (vide Lect. XI., p. 222), has really an important therapeutical value; it has not as yet been of any service to me in various trials which I have made of it, any more than it has been to others, and it has lately fallen completely into oblivion.

Finally, a method which is applicable here must not be omitted, viz. *the treatment of certain painful and tender spots*, which has undoubtedly excellent results in many cases (Moritz Meyer, Brenner, Onimus and Legros; see also Obs. 27, 28, and 29, given above). I have already said what was necessary about this method in the General Part (see Lect. XIV.) Wherever such painful spots are discovered, either by pressure or by testing with the kathode (according to Brenner), they must be made the subject of therapeutical experiment (the anode stabile over these points, with a weak current). Unfortunately the occurrence of such tender and painful points is by no means frequent; I at least have often looked in vain for them.

But the electrotherapeutical tasks are often not exhausted by the employment of all these methods; a whole series of *symptoms* may be the subject of special electrical measures, such as the paræsthesiæ and anæsthesiæ, the hyperæsthesiæ, pains, and neuralgias which occur in so many spinal diseases. More frequently pareses and paralyses and their accompanying muscular atrophy, with the rarer symptoms of motor irritation, such as spasms, muscular rigidity and contractions; or weakness of the bladder and rectum, pollutions, spermatorrhœa and impotence, may require a specially directed electrical treatment; indeed, even for decubitus the application of the galvanic current (in the form of a simple galvanic element) has been advised (Hammond). I shall give you more details about these modes of procedure in the course of subsequent lectures, and I shall also mention some of them in treating of the individual spinal diseases themselves. But in all cases the methods to be employed must always be chosen with special reference to the fundamental spinal affection, and the symptomatic treatment must always be merely an adjunct to the direct treatment of the cord of the fundamental disease, which must in all circumstances be the chief consideration.

LECTURE XX.

Treatment of the Individual Spinal Diseases—Electro-diagnostic Preliminary Remarks: 1, Spinal Meningitis; 2, Meningeal Apoplexy; 3, Functional Spinal Diseases, Concussion, Spinal Irritation, Spinal Neurasthenia; 4, Hæmorrhages into the Spinal Cord, Severe Traumatic Lesions; 5, Myelitis, Multiple Sclerosis; 6, Tabes Dorsalis, direct Galvanic Treatment, Treatment of the Tender Spots, Farado-cutaneous Brushing; 7, Spastic Spinal Paralysis; 8, Acute Anterior Poliomyelitis (Spinal Infantile Paralysis); Electrical Diagnosis, Electrical Treatment; 9, Subacute and Chronic Anterior Poliomyelitis; 10, Progressive Muscular Atrophy, Behaviour of the Electrical Irritability, Juvenile Form, Methods of Treatment, Amyotrophic Lateral Sclerosis; 11, Acute Ascending Paralysis; 12, Secondary Degenerations.

Before proceeding to give you a short account of the treatment of the individual forms of spinal disease, I must mention that, with reference to their *electro-diagnosis*, every possible alteration of the electrical excitability may occur in them. The phenomena depend almost exclusively on the implication of the grey substance in the lesion; if a portion of it is affected, and severely injured, RD, either partial or complete, appears in the corresponding neuro-muscular region; this fact is of great importance for the prognosis in many cases, for it points to a rapidly advancing atrophy of the muscles. But if the grey substance (the anterior columns) is not implicated, there is no qualitative change in the excitability, or, at all events, no degenerative reaction. Various grades of simple diminution, rarely of increase, in the electrical excitability may, however, be observed. The diminution is mainly caused, in such cases, by the consequent inactivity of the motor apparatus; also, no doubt, partly by the influence of the disease. This diminution may become very marked indeed, without any qualitative alteration, and it is then associated with simple, not degenerative atrophy (vide p. 165). In solitary cases, qualitative anomalies of irritability have been found in individual motor nerve-trunks (vide p. 212). I shall enter more minutely into these topics, which are of so much practical importance, in dealing with the separate forms of disease.

We pass now to the consideration of these separate forms.

1. *Spinal meningitis* will become the subject of electrical treatment only in its chronic or subacute form. Its symptoms may be very various; pain and stiffness in the back, paræsthesiæ and excentric pains in the extremities, motor irritability and weakness, seldom actual paralysis and atrophy, more or less extensive anæsthesia, weakness of the bladder, &c., may occur in varied combination, often characterised by a certain changeableness and great fluctuations. The electric excitability presents no characteristic condition; only if the anterior roots are severely injured, atrophied, and degenerated, there is diminution of the reactions and RD, but it is very seldom that any sure point for the main diagnosis can be drawn from this fact.

The *treatment* must in the first place be directed to the attainment of katalytic actions: stabile currents, therefore, through the cord, as much as possible throughout its whole extent, both poles on the spine, passing from point to point in succession from the nape of the neck to the loins. If irritative symptoms are prominent, you must give the anode the greatest influence, and must employ the descending current, the kathode being placed as low as possible on the sacrum. This unipolar action will be still more certain if the kathode is placed on the anterior surface of the body. The strength of the current must be moderate, especially at the beginning, but the duration of the sitting may be considerable (four to ten minutes). Individual symptoms often require other special measures.

2. In *meningeal apoplexy* (sudden apyretic onset of irritative meningeal symptoms with rapidly developing paraplegic paresis or paralysis, which generally begins quickly to recede) the employment of the galvanic current is of distinct service in the stage of absorption and commencing convalescence. The *application* must be modified according to the seat of the hæmorrhage, and its probable extent; the stabile action of the current, of both poles successively, is advisable here in order to obtain the katalytic action for absorption and nutrition. You must also resort to peripheral treatment of the possibly paralysed, anæsthetic or atrophic parts.

3. *The functional spinal diseases* seem, *a priori*, to be among the most favourable subjects for electrical treatment. But these expectations are often radically deceptive, and every possible method of electrisation may be employed in vain to cure spinal irritation or severe neurasthenia. This may often depend upon the fact, that these very affections develope upon the foundation of a severe neuropathic disease, which can, naturally, not be cured so easily; but very favourable and cheering results are often seen, especially in neurasthenia, in the sequelæ of a simple concussion, &c. Electrical examination does not give any notable result in the majority of such cases; sometimes, when the consequences of the concussion have been more chronic in character, I have seen a diminution, and sometimes even an increase in the electrical excitability, but this could only be discovered after a very thorough investigation. In one case I saw the original increase gradually pass into diminution of the electrical excitability.

In *concussion of the spinal cord* you will, as a rule, have only the consequences to treat—slighter forms of functional disturbance, weakness, &c., caused by minute nutritive disturbances—or more severe, more permanent, and perhaps progressive functional disturbances, caused by insidious myelomeningitis supervening on the concussion (railway spine). In the latter case, the treatment is the same as in cases of similar nature arising from different causes; in the former case, we have to do partly with a direct or indirect stimulation of the spinal functions, and partly with a direct or indirect influencing of the nutritive and circulatory relations in the cord. You may employ, therefore, very various methods of treatment: *galvanisation of the spinal column* with stabile and not too strong currents, ascending and descending: the most active pole to be chosen according to the principal symptoms, to be followed by the symptomatic treatment of the most prominent peripheral disturbances. Further, *faradisation of the spinal column*, as Löwenfeld has recently recommended, with general faradisation also, or, still better, electric baths, especially in general weakness, want of tone, impaired nutrition in delicate women, &c.; and, finally, perhaps also *cutaneous faradisation*, especially in cases where symptoms of sensory irritation—neuralgias—are present, or where there are distinct signs of hyperæmia or anæmia of the cord.

True *spinal irritation*, the form of spinal nervous debility accompanied by prominent irritative symptoms, pain in the back, tenderness of the vertebræ, neuralgias, extreme vasomotor irritability, motor weakness and exhaustion, symptoms of motor irritability, sleeplessness, as well as all manner of hysterical symptoms, is certainly a complaint most obstinate to electrical treatment, but sometimes brilliant results may be obtained. The treatment employed may be the same as in concussion, but it should be carried out with great caution and with very feeble currents, as every attempt at more energetic action is apt to injure the patients. In many cases an ascending stabile current, through the spinal column from the sacrum to the nape of the neck, is sufficient, or applied in such a manner that the specially painful parts come between the two poles; weak currents and short sittings are imperative. A trial may then be made with the anode stabile on the specially painful vertebræ, with a weak current, for from three to ten minutes; but in many cases the kathode, used in the same way, has better results. You may also try direct, moderately strong *faradisation of the spinal column*, according to Löwenfeld; with prominent symptoms of irritation *the farado-cutaneous brushing* also, followed by the application of the faradic brush right over the painful spinous processes (as a counter-irritation); and *general faradisation*, which must, of course, be tried with careful graduation of the current and of the duration of the sitting, appears to have an excellent effect in many cases, as have also electric baths. *Central galvanisation* may perhaps be tried with benefit in certain cases, especially if cerebral symptoms are present at the same time. It is just in such cases, often very obstinate and tedious, that a number of methods must be successively tried. The impression is nevertheless often made by these forms of disease, that, if they are susceptible to electrical treatment at all, they yield to any method employed in a rational manner, and conversely that where one method does not answer, the others generally fail also.

Very different methods of electrical treatment may be employed in the most frequent functional spinal disease, *spinal neurasthenia*, with its prominent symptoms of debility and exhaustion in all possible regions of the spinal nervous system (motor weakness, paræsthesiæ, sexual debility, &c.) There are two that are specially deserving of a trial: *galvanisation of the spinal column* with ascending stabile currents, including, eventually, the cervical sympathetic; and *general faradisation*, to which great results in this very department have been justly attributed. We may still more particularly recommend electric (especially faradic) baths, which prove highly useful in those forms characterised by sexual debility. The treatment must be conducted cautiously, the action of the current being gradually increased, and it must generally be continued for a long time. If you do not attain your end by these means, you may try the treatment of painful points in the spine, or cutaneous faradic brushing, perhaps also central galvanisation. To this you may add, in suitable cases, the peripheral treatment of the legs, the genitals, the cervical sympathetic, and the head (in sleeplessness, depression, &c.) In the presence of the great uncertainty which still exists with regard to the diagnosis of *hyperæmia* and *anæmia of the cord*, more exact discussion of their electrical treatment is unnecessary. You will employ the same methods, *mutatis mutandis*, as in the treatment of cerebral hyperæmia and anæmia. For hyperæmia a trial may be made with Rumpf's method of farado-cutaneous brushing; for anæmia I would first try the galvanic current, especially the stabile action of the anode.

4. *Hæmorrhages into the cord*, which are rare on the whole, may be treated according to the very same rules as hæmorrhages into the brain. In these cases we have to deal chiefly with severe paraplegias with bad prognosis, in which we can resort to electrical treatment only after the threatening symptoms have disappeared, if life is still preserved and if a chronic stage has been entered upon. According to the seat of the hæmorrhage we shall have paraplegia with anæsthesia, paralysis of the bladder, with or without muscular atrophy and its concomitant

RD; the last-mentioned symptom occurs regularly if the hæmorrhage is in the cervical or lumbar enlargement, when a more or less extensive atrophic paralysis is the inevitable consequence.

There is not much to be expected from galvanic treatment in such cases, for the destructive action of the hæmorrhage is generally so great in such a narrow space that the most part of the affected nerve tissue is irrevocably lost. Still one may always hope to preserve from complete destruction and to restore to a moderate functional activity parts which are not quite broken down, but are only mechanically affected, or injured by the subsequent inflammation. To this end an attempt at least may be made with electrical treatment. The seat of the lesion can generally be determined without difficulty; a large electrode must then be applied exactly over it, *first the anode, then the kathode*, the indifferent pole being applied above or below to the back or to the sternum; this should be done for several minutes, with a stabile current. Very little is to be expected from the faradic current. The peripheral symptomatic treatment of any anæsthesia, paralysis and atrophy, paralysis of the bladder, atony of the intestine, &c., must be proceeded with, along with that of the lesion.

You must proceed in exactly the same way in severe *traumatic lesions of the cord* (punctured, incised, or gunshot wounds, contusion from fracture or dislocation of the vertebræ, severe concussion, &c.), if life should be preserved in these cases, and if they should pass into the chronic stage of permanent paraplegia. You must not expect much in such cases, and yet one cannot pronounce upon them beforehand, as the case mentioned above (Obs. 22) of gunshot wound of the spine teaches us. Even in more severe and long-standing cases I have often done the patient much service by restoring the functions of individual muscles, and relieving other symptoms.

5. *Myelitis* in its various forms offers the most manifold indications for electrotherapeutics, and may call for the most diverse methods of application. We shall obviously have to deal chiefly with the subacute and chronic varieties; the employment

of the current ought certainly to be avoided in the early stages of an acute myelitis, and ought to be kept for the last traces of the disease and for the sequelæ.[1]

The seat, the extent, and the severity of the chronic myelitis, perhaps also its cause (concussion, chill, neuropathic injury, syphilis, &c.), will naturally modify considerably the therapeutical result to be expected.

If we disregard the varieties limited to the grey anterior columns (poliomyelitis) and the columnar degenerations (systematic diseases, tabes, lateral sclerosis), the ordinary forms of chronic myelitis (transverse myelitis, multiple sclerosis, central myelitis, myelitis by compression, universal progressive myelitis, chronic myelo-meningitis, &c.) offer for the most part very few chances to electrical treatment. But still one comes now and again on cases in which the electrical treatment is of obvious advantage, in which great improvement and even complete cure is effected by its persistent and repeated employment, or where at least marked and long-continued remissions in the disease are brought about. I have seen this repeatedly in transverse dorsal myelitis; the myelitis by compression offers also comparatively good chances, in so far as it depends upon a curable cause (Pott's disease), and even in multiple sclerosis I feel obliged sometimes to ascribe the intermissions partly to the influence of the electric treatment. From this we see that it is certainly our duty to make at least a systematic and thorough trial with electrisation in all such cases, as we cannot decide beforehand whether the individual prognosis is favourable or unfavourable.

The *persistence of the electrical excitability* varies very much, in chronic myelitis, according to the seat, the extent, and the severity of the lesion; in some cases it furnishes a very valuable basis for more exact diagnosis, though in others no important conclusion can be drawn from it. In the greater number of cases the electric excitability remains normal in quantity and quality (as, for example, in transverse dorsal myelitis); I have been able to find a distinct increase in the faradic and galvanic excitability in the nerves of the paraplegic limbs only in isolated cases, while a small degree of quantitative diminution is more frequent, especially when the disease has lasted for some time. It is said that in some cases simple diminution has been found to a large extent, *without* qualitative anomaly; that has not yet come under my observation; on the other hand, I have often found RD, either partial or complete, to be present where the grey anterior cornua of the cervical or the lumbar enlargement were implicated in the focus of disease; well-marked degenerative atrophy of the muscles and disappearance of the reflexes are always associated with this condition, and they may, therefore, often be taken as very valuable data for the exact localisation of the lesion.

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[1] In Lewin's case the diagnosis of acute myelitis was too uncertain to enable it to serve as a foundation for definite indications.

The electric current can be of use in these forms of disease only on account of its katalytic effects, and therefore the direct treatment of the diseased point by the galvanic current is the method to be employed before any other. All the methods of application which have been already given may find a place here; for more circumscript diseases the successive use of both poles, stabile with a moderate current and not too long duration of the sitting (one to five minutes); for the more diffuse or the columnar diseases, longitudinal passage of the current, with alteration of the points of application of the poles, subsequently with the inclusion of the cervical sympathetic. Tender points must be looked for, and when they are found, the anode must be applied stabile to them. In myelitis by compression through kyphosis, apply the electrodes immediately above and below the curvature. To this may then be added the peripheral symptomatic treatment of the most important functional disturbances. Hardly anything is to be expected from direct faradic treatment; but, on the other hand, it appears likely, from various observations, that the reflex action by means of farado-cutaneous brushing or general faradisation has been sometimes beneficial.

In *multiple sclerosis* the treatment of the brain according to the methods mentioned above (longitudinal and transverse or diagonal passage of the current through the head, treatment of the cervical sympathetic, &c.) must, of course, be added to the treatment of the spine.

6. *Tabes dorsalis*, certainly the most important and the most frequent of all chronic spinal diseases, has long been the subject of electrotherapeutic experiments, and has been specially taken in hand, with greater effect, since Remak's favourable results, the electric current being to-day one of the most important remedies for tabes. It is true the results are not brilliant in this melancholy disease, and I must here warn you very specially against delusions. True recovery, or an improvement bordering on recovery, occurs only in a very small percentage of cases; in the greater number you will attain a more or less extensive improvement, but in the remainder your efforts will be fruitless, and the disease will advance steadily. The theory which is gaining increasing probability from every new and unprejudiced observation, that tabes may be referred to syphilis in an immense majority of cases—a cause which grows daily in certainty, in contradistinction to the causes repeatedly and with lamentable results brought forward by its opponents—this theory certainly makes the futility of such efforts appear conceivable.

But even here we cannot pronounce beforehand on the cases, whether the prognosis is favourable or unfavourable; only therapeutical experiment and the subsequent course of the disease can decide. Sometimes the disease advances with remarkable rapidity to its worst stages, in spite of all attempts at cure, at another time the progress is very much slower, and it may remain at a standstill for years and decades. You will, of course, expect less from the electrical treatment the farther the affection has already advanced, the more its principal symptoms (ataxy, sensory disturbances, alterations in the pupil, atrophy of the optic nerve, weakness of the bladder, &c.) have developed; that is, the more reason you have for assuming advanced grey degeneration of the posterior columns;—the sooner you begin the electrical treatment, the better. The more recent advances in the diagnosis of tabes permit a certain recognition of the affection, even in its very earliest stages, from a series of very important premonitory symptoms (lancinating pains, paræsthesiæ, weariness in the legs, absence of the tendon reflexes, Argyll Robertson pupil, analgesia, and retardation of the conduction of pain, swaying or closure of the eyes, paralysis of the ocular muscles, vesical and sexual debility, &c.);

so that a chance of the earliest possible treatment is granted to most patients, a chance which is of value, because in this stage *great* anatomical changes are not to be presupposed, but only commencing nutritive disturbances in the region of the posterior roots.

In spite of all this, even in such cases, with the earliest possible commencement of treatment, the prognosis must be regarded as dubious in the highest degree, and only therapeutical experiment can furnish light on the subject. Those cases with very severe lancinating pains, and those characterised by a very rapid advance to a great degree of ataxia, appear to me to be specially unfavourable; and those with predominating sensory disturbances, weakness of the bladder, and motor debility, comparatively more favourable; but these are only indefinite impressions.

I have found the *electric excitability* in tabes quite normal in many cases; there were at least none of the grosser changes, even with very careful examination. But in a number of tabetic patients I discovered a slight increase of the faradic and galvanic excitability in the peroneal nerves, without any qualitative alteration; this appeared to be the case chiefly in comparatively recent cases. Finally, in another set of patients I found some diminution of the faradic and galvanic reactions in the peroneals, but without qualitative alteration; these were mostly, but not all, older cases, of which I have already given a sufficient number of examples (see Lect. IX.); I need not multiply them here, as the subject is of no diagnostic importance. *Quantitative alterations in the contractions* occur in the nerves only in isolated cases (see Lect. XI.); but I have never been able to see the reputed greater tendency to OC in tabes; RD occurs only in the very rare cases of complication with disease of the grey anterior columns.

I have already mentioned and proved (see Lect. XI.) that *the farado-cutaneous sensory test* is an excellent means of recognising disturbances of the cutaneous sensibility in tabes, and I have also given you, in the same place, a short statement of my experiences on the subject.

For *treatment* the *direct action of the galvanic current* on the cord must, of course, be first selected. The methods employed by the different writers for this purpose differ very little from each other. R. Remak treated the portions of the cord, diagnosed by him to be specially affected, with tolerably strong, stabile currents; v. Krafft-Ebing advised simply sending stabile currents through the spine, no matter in what direction, and Mendel has also employed stabile and labile currents to the spine. Flies has been the first to try systematic treatment of the cervical sympathetic, along with direct galvanisation through the spinal column. I myself usually employ in tabes the method described above (p. 382) of treatment to the spinal cord, including the cervical sympathetic, with special reference to the cephalic symptoms, which are usually present at an early stage (ocular paralysis, alterations of the pupil, &c.) and which may perhaps be influenced favourably by the action on the base of the skull, and on the cervical cord. I have every reason to be satisfied with this method. The treatment of the back occupies from three to five minutes, and the strength of the current must be very carefully chosen; strong currents and long sittings are liable not to be so well borne. The sittings should be daily, and should generally extend over a number of months.

You may very profitably combine with this central treatment peripheral galvanisation of the nerves of the lower extremities (with the kathode labile, the anode being on the spinal column). Faradisation of those nerves is also found useful by many patients.

We have now to mention the *symptomatic peripheral treatment* of the various tabetic symptoms, such as ocular paralysis, atrophy of the optic nerve, anæsthesia, vesical debility, &c., according to the methods to be described later. Sometimes good results may be obtained with regard to the *lancinating pains* with the most varying methods—stabile action of the anode to the spine over the region of the roots of the painful nerves; stabile action of the kathode on the painful and hyperæsthetic portions of skin themselves (sometimes with magical effect for the moment), the anode being at the same time on the corresponding region of the root of the nerve; 'swelling' faradic currents to the same points; application of the faradic brush to them and to more diffused cutaneous regions on the back and on the lower extremities, &c.: you may choose among these in suitable cases, but often all these methods are alike fruitless.

Two other methods, however, deserve mention and a trial in appropriate cases. The one is the *treatment of the spots tender on galvanism or on pressure* with the stabile action of the anode, as it has been recommended by Moritz Meyer, Brenner, and others, and practised repeatedly with the best results. I myself have recently collected some observations in support of this; the only pity is that the cases in which such painful spots are found are so very rare. Under this treatment the painful spots, with their accompanying girdle-pains, are first seen to disappear, and then generally an improvement in all the other symptoms to follow.

The other is the *farado-cutaneous brushing*, repeatedly recommended by Rumpf, some good examples of which I have quoted above (Obs. 30 and 31); the method, which I have already described (Lect. XIII. ad fin.) consists in powerful faradic brushing of the skin of the back and of the extremities, for about 10 minutes daily or on alternate days. The surprising results, which Rumpf has recently published in Strasburg, of this method of treatment (sometimes combined with anti-syphilitic treatment), in a series of twenty-four cases of tabes, among which there were four of complete cure, ten very considerably improved, and only one where no permanent benefit was experienced, invite us to further researches, and have already received confirmation from other observers.

7. In *spastic spinal paralysis*, so far as it is characterised by a systematic degeneration of the pyramidal tracts (which is probably the case in all uncomplicated cases), the same galvanic treatment as for tabes, or any diffuse myelitis, is suitable, i.e. direct treatment of spine, generally combined with galvanisation of the legs.

The *electrical excitability*, in this affection, presents either no anomaly whatever, or, as I have seen in nearly all minutely investigated cases, a small degree of diminution of the faradic and galvanic excitability. (For examples see the observations recorded in Lect. IX.)

When not quite clear with regard to the diagnosis, paralysis being present and a slight improvement alone attainable, you suspect a commencing myelitis dorsalis lurking behind the symptoms of spastic spinal paralysis, a first beginning of multiple sclerosis, or even what seems not rare in children, some affection of the brain (chronic hydrocephalus), you must adopt the suitable treatment for such affections. I have repeatedly had good results in cases of spastic spinal paralysis.

8. With regard to the *acute anterior poliomyelitis* (the so called infantile paralysis, acute atrophic spinal paralysis) all experienced physicians are agreed that it offers a thoroughly appropriate, even if a somewhat toilsome, field for electrical treatment.

We understand under this name those forms only of paralysis which come on very acutely, often with high fever and severe cerebral symptoms, characterised by rapid degenerative atrophy and RD, without disturbances of the bladder or of sensibility, in which the paralysis attains its greatest degree at the beginning and shows no tendency to advance or may even recede a little, but remains for the most part permanent and stationary—a paralysis which depends upon acute inflammatory processes in the grey substance of the anterior columns, having its favourite seat in the cervical and lumbar enlargements. It is a form of disease which occurs by far the most frequently in children, although now and then in adults also, and which often results, especially in the case of children, in very grave and permanent paralyses and deformities.

The *conditions of electrical excitability* are of no less diagnostic and prognostic importance in this disease; they have been established by Duchenne with an accuracy useful for all practical purposes, in spite of his one-sided, exclusively faradic method of investigation. He found that the faradic excitability remained intact in a part of the paralysed muscles, or was only diminished to a small extent, and that these muscles recovered their motility very rapidly, atrophying not at all or only temporarily; but that in another part, generally the greater, the faradic excitability was extinguished rapidly and completely, and that these muscles then atrophied with corresponding rapidity and completeness, and generally remained permanently paralysed after years of exertion. These faradic investigations furnished very important data.

We know now that this loss of faradic excitability is nothing else than a constituent part of the RD which makes its appearance in the wasting muscles; since Salomon first pointed out this fact, it has been regularly found after thorough investigation, and we may now say that RD must be looked upon as a constant symptom in acute anterior poliomyelitis.

But this 'thorough' investigation is usually surrounded with very great difficulties, at all events in the case of little children; there are certainly no less satisfactory objects for electrical investigations than these little screaming, wriggling patients, who, with the unimpaired sensibility of their skin, dread the electrical application in the very highest degree, and in whom, besides, the abundant adipose tissue interferes very considerably with the localisation of the current and the demonstration of its effects. It is usual also for patients to appear only in the later stages, when the galvanic excitability is very much lessened, a fact which stands in the way of the diagnosis. Under such circumstances we must limit ourselves, in most cases, to a superficial recognition of the RD, which may be shown by a few closures or reversals of the galvanic current and by a short faradic testing of the nerve trunks. The retardation of the contractions and the preponderance of the ACC are specially characteristic. In recent cases, however, where increase of the galvanic excitability is still present, or in adults, the full demonstration of the RD does not offer the slightest difficulty.

Complete RD is then found, as a rule, to be present in most of the affected nerves and muscles, and partial RD may occur along with it here and there—as Franz Müller, in particular, has pointed out—although this occurrence is by no means frequent. It appears to me not yet settled with sufficient accuracy whether in certain slight cases—the so called 'temporary' forms of infantile paralysis—the RD may be wanting entirely in *all* the affected groups of muscles, but it is quite possible.

The symptoms of RD are also wanting in the partially regenerated muscles; but after very long continuance of the affection there is generally nothing more to be perceived distinctly in the highly atrophic muscles, as they are almost entirely unexcitable.

The *indications* and the *methods of application* of the electric current may here be laid down with greater simplicity and precision than in almost any other spinal disease; we have to do with small, sharply localised spots of inflammation, with their consequences, and with secondary degenerative atrophy of the peripheral motor nerves and muscles, just as in every severe traumatic paralysis; further symptoms are not present. We should be inclined to think that electrotherapeutics would here have a particularly favourable field of action. But this is unfortunately not the case: experience has taught that this affection has an almost universally bad prognosis in respect of complete recovery—that those nerve elements which have been destroyed by the unknown inflammatory process cannot possibly be restored; in other words, that the resulting paralysis and degenerative atrophy are irreparable. Be very moderate, then, in your expectations from the result of the treatment, and very guarded in your prognosis to the patient or his friends. You will have rapid and complete recovery only in the slight, temporary forms; in the usual severe forms, on the other hand, you will, at the most, see the slightly affected muscles resume their functions at the commencement of the treatment, while the more severely affected ones improve only to a very small extent. Still it is possible, in not a few cases, to strengthen and revive separate muscles and portions of muscle by long-continued treatment, and thereby to procure great advantages to the patient—to restore certain movements, to give somewhat greater firmness to the joints, &c.

We have to do with very small spots of inflammation, situated in the enlargement of the cord, resulting in sclerosis, with complete destruction of the nerve elements; the sooner treatment is begun, the more chance there is of conquering the disease, of saving what is not yet quite lost, and of preserving the only half-degenerated nerve elements from complete disintegration. Begin the treatment, therefore, as early as possible, as soon as the acute inflammatory stage is over—for everything depends upon the first weeks after the acute attack; after this you will not be able to effect much alteration in the diseased portion.

The direct treatment of this diseased part is, therefore, the principal thing; it must, of course, be carried out with the galvanic current, by means of stabile action on the cervical or the lumbar enlargement, or on both. You cover the diseased spot with a 'large' electrode, while you apply the other to the anterior surface of the body, or to some other suitable indifferent point, and allow first the anode, then the kathode to act for one or two minutes, each with a moderately strong current (15°–40° N defl., 150 GR–3–10 ma., or more in adults). If both enlargements are diseased, you may place one pole over each of them, and let the current flow through, first in one direction, then in the other.

To this you will add *peripheral galvanisation* of the paralysed nerve-muscle regions, with the kathode labile, while the anode remains fixed over the diseased point; in the later stages you must employ kathodic closures, and reversals of the current, which must be tolerably strong. Faint, sluggish muscular contractions often do not show themselves until after continued treatment. This treatment is for the purpose of acting antagonistically to the degenerative atrophy—of preserving the muscles for the future, until spontaneous contraction shall be again possible. This indication is generally fulfilled very imperfectly, but sometimes we succeed in a very surprising manner; you must therefore not grudge the time and trouble which you spend on this peripheral treatment.

The whole treatment must be continued for a long time and with great perseverance; if you have begun early, you must go on for six months or a year continuously—this is the time during which most can be accomplished. Afterwards and in all long-standing cases it will be sufficient to galvanise twice a week for two or three months at a time (about forty to sixty sittings), and to fill up the intervening periods with other remedies—baths, massage, gymnastics, &c. It is not rare to see the improvement making more rapid progress when treatment is resumed after a long pause. It is at all events advisable to continue the treatment as long as even a small amount of progress is being made under it.

The *faradic current* also has produced some results in this affection; its direct application to the diseased part can certainly be of little service, but, on the other hand, we know from Duchenne's large experience that the peripheral faradisation of the paralysed muscles, in so far as they have retained their faradic irritability, has generally a beneficial effect. Good results have been credibly reported even in muscles which had completely degenerated into RD: this is difficult to explain, if the fact is correct. A peripheral irritation of the trophic tracts can hardly be assumed; it is more likely that a reflex action is exerted on the diseased spot through the perfect integrity of the centripetal, sensory tracts. We shall afterwards see besides, with regard to the paralyses, that the setting up of an energetic excitation *centrally* to the seat of lesion contributes very much to the removal of the paralysis. As here the sensory conductivity is quite intact, similar stimulating influences may be exerted on the motor tracts in the cord from a point situated centrally to them, by means of reflex irritation, and, therefore, the peripheral irritation of the mixed nerve trunks, and even the farado-cutaneous brushing (which is certainly very difficult with children), may not be so absurd as perhaps they appear to many at first sight.

Under all circumstances this disease calls for care and trouble from the physician no less than for patience and perseverance on the part of the patient.

9. The various forms of *subacute and chronic anterior poliomyelitis* give a much better prognosis for electrical treatment. This form of disease is characterised by a more or less rapidly developing and slowly progressive atrophic paralysis, generally paraplegic in form, now and then decidedly ascending in character, without any disturbance of the sensibility, the sphincters, or the cerebral nerves—an atonic paralysis with rapid atrophic degeneration of the muscles, with partial or complete RD. Its course is generally favourable, the paralysis soon ceasing to advance, improving, and sometimes even becoming completely cured. Its anatomical ground is doubtless to be

found in a nutritive disturbance of the grey anterior columns (inflammatory?), but one which has evidently not the same deleterious character as in acute poliomyelitis.

The *electrical examination* shows one of the most essential characteristics of the disease—RD in every possible stage of its development and without any other peculiarity. The complete form is usually found, but, there are also cases with only partial RD, whose prognosis is more favourable; partial RD in some nerve-muscle regions may be seen to exist alongside of complete RD in others, or even in one and the same nerve-muscle region the RD which was only partial at first may gradually merge into the complete form. Many kinds of rarer anomalies too, partial RD with every variety of delayed contraction, are found with comparative frequency in this disease. The electrical sensibility returns gradually to normal with the cure of the disease.

The *electrical treatment* consists in the employment of the galvanic current to the spine, according to the methods which are already sufficiently well known to you, which will be determined at the time by the localisation and extent of the process. As the enlargements of the cord are most likely to be the seat of the affection, you will bring them specially under the influence of the poles, and of both poles successively, with stabile currents of sufficient strength. To this you will add the peripheral treatment of the paralysed and atrophic nerve-muscle regions, with the kathode labile, reversals of the current, &c., according to necessity. You may generally dispense with the faradic current in this disease, although it may be employed in partial RD for peripheral irritation of the nerves and muscles.

The *result* is generally very satisfactory. I have repeatedly seen the use of the galvanic current followed by immediate improvement in such cases, and after a short period of treatment the improvement is generally very decided (vide Obs. 33 and 34). The affection may, however, be sometimes very wearisome and require long-continued treatment. The number of the cases hitherto treated is too small to determine when the treatment had best be begun *a priori*; I would say as soon as possible, but in pyretic cases it is certainly best to await the abatement of the fever.

10. *Progressive muscular atrophy*, in its typical form undoubtedly a spinal disease, and best to be understood as a disseminated, progressive degeneration of the grey anterior columns, is characterised principally by a steadily progressive degenerative atrophy, beginning in certain groups of muscles and extending slowly over a great part of the voluntary muscular system, with fibrillary contractions, and by subsequent paralysis and complete disappearance of the muscles, without disturbance of the sensibility, the sphincters, the cutaneous nutrition, the brain, or the cerebral nerves; to this the combination with progressive bulbar paralysis may be finally added. The disease may easily be distinguished, according to this definition, from similar and allied forms; and yet a great deal which does not belong here is often included under this name.

The *electrical examination* furnishes important data, in my opinion, for differential diagnosis. In the first beginning of the disease certainly there is no decided anomaly to be proved, and even after it has lasted longer there is only a simple diminution of the faradic and galvanic irritability in many of the nerves and muscles, corresponding to the degree of the atrophy. Later, however, with the advance of the degeneration, indications of RD show themselves, becoming gradually more and more distinct. The anatomical changes would lead us, *a priori*, to expect this with certainty, being, as they are, identical with those in traumatic paralysis or spinal infantile paralysis, except that here the muscles are not affected diffusely, but in a more disseminated manner, fibre by fibre.

The RD is at first only partial—that is to say, the faradic irritability is diminished, not abolished—but the galvanic irritability of the muscles is altered in a characteristic manner—sluggishness of contraction, preponderance of ACC, generally with lowered irritability. In a later stage, especially if the atrophy has proceeded far, complete RD is found. This change occurs most frequently and is most easily demonstrated in the small muscles of the hand, thenar, hypothenar, and interosseous, but I have been able to find it occasionally in other muscles also, in the flexors of the forearm, the biceps, the deltoid, &c., and I am obliged to regard this RD as a regular occurrence in *typical* progressive muscular atrophy, in spite of the contrary views which are continually being uttered; at least I have never found it wanting in the tolerably numerous cases which have come before me since my first publication. It is certainly not easy to demonstrate in many cases, and requires very careful investigation and much practice in the recognition of RD; the matter is also much complicated by the anatomical peculiarity of the disease, the process developing slowly and in a disseminated manner in the muscles, so that a number of sound fibres always remain side by side with those which are degenerated; the irritability of the motor nerves remains intact, and the neuromuscular contractions proceeding from them may mask the qualitative changes. It depends, no doubt, chiefly upon the relative proportion of the degenerated and the non-degenerated fibres whether the RD is easy or difficult of demonstration: if many fibres are degenerated it is easy; if only a few, then it is difficult or impossible. And even if many are degenerated, but if the process has advanced very slowly, so that the fibres are already very much diminished in irritability, the increase in the strength of the current which is thereby rendered necessary may influence the few normal fibres so strongly that their contractions will preponderate. You will have to employ here all the conditions of investigation which I have already mentioned (p. 202), and especially to notice the double contractions, in order to detect the traces of RD in progressive muscular atrophy. This will be very easy only in muscles which atrophy quickly and in a more diffused manner; in such you may even be able to demonstrate the stage of increased irritability; in slowly advancing and disseminated atrophy, on the other hand, this is very difficult, and there the RD can only be recognised in its latest stages, in the much atrophied muscles, with greatly diminished irritability. As the course of the atrophy may be very different in different cases of the disease, and, again, in each case in the different muscles, it is plain that the results of the electrical investigation must be very various, and from this it follows that RD can be found only in separate muscles in this disease.

There is one form of so called progressive muscular atrophy, which I formerly described under the name of 'juvenile muscular atrophy,' connected with pseudo-hypertrophy of the muscles and with the so called hereditary muscular atrophy, and which I pointed out as one to be sharply divided from the typical spinal form, and as, perhaps, primarily myopathic (dystrophia muscularis progressiva). I see with satisfaction that this view is now pretty generally accepted by Landouzy and Déjerine and by Charcot, in connection with Duchenne's infantile progressive muscular atrophy.' In this form I have *never* found RD, but only a simple diminution of the faradic and galvanic irritability, corresponding to the degree of atrophy. This has been almost universally confirmed, and it still remains doubtful whether or not some exceptions may occasionally be found (vide Lect. IX. par. 2).

Ever since progressive muscular atrophy was known electricity has been recommended as the most important, almost the only remedy for it. But critical experience unfortunately teaches us that even the electrical current is no real *cure* for this sad disease. The typical form of the affection is very little accessible to therapeutical influences, and may be regarded as incurable. The numerous and sometimes even brilliant curative results said to have been attained in this disease are generally the consequence of errors of diagnosis, as the clinical histories have shown, and especially of the cases having been confounded with acute anterior poliomyelitis, chronic neuritis, multiple progressive neuritis, atrophy after joint affections, &c., a confusion which occurs, unfortunately, only too often even nowadays. I, for my part, have never seen recovery in the true, typical form of the disease, but I have seen improvement, relief, retardation of progress, and sometimes an arrest of the affection in individual cases, especially those which have early come under treatment, and once even where the disease was considerably advanced; nevertheless I will not deny the possibility of a cure, or at least of an arrest, of the morbid process. The above-mentioned dystrophia muscularis progressiva (especially the variety known as 'juvenile muscular atrophy') has a much better prognosis, at least in regard to the arrest of the disease; I have seen very considerable improvement take place even in very long-standing cases of this kind.[1]

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[1] The observations 13 and 14 of C. W. Müller, published as a cure of 'progressive muscular atrophy' and 'pseudo-hypertrophy,' leave room for such important diagnostic doubts that they cannot prove much.

According to our views of the nature of the disease, the *galvanisation of the spinal cord* must of course play the chief part in its electrical treatment Only a secondary influence can be ascribed to the sympathetic, according to the most recent experience; still you might include these nerves in the treatment for various reasons, especially when you have to do, as is most common, with the localisation of the disease in the cervical cord. The position of the atrophy in the several groups of muscles gives an exact intimation of the position of the disease in the cord; the cervical enlargement is most often the chief seat of the lesion, then comes the lumbar enlargement and the dorsal cord, and finally the medulla oblongata is sometimes involved. Following those indications, it is very easy to select the method of treatment. I generally begin with galvanisation of the cervical cord and the sympathetic, the anode being placed on the cervical enlargement; then the stabile action of the kathode on the same point, the anode being placed on the sternum, and subsequently on the lumbar enlargement or the peripheral nerves, the important point being that the stabile action of both poles successively should be brought to bear on all the diseased portions of the cord with a moderately strong current.

Then follows regularly a moderately strong galvanisation or faradisation of the specially affected nerve-muscle regions, with the kathode labile, the anode being placed on the seat of disease in the nape or in the lumbar region. You must avoid too strong currents in this peripheral application; they may easily do harm, and an excessive irritation would be very likely to hasten the degenerative process in the muscles. The condition of the patient immediately after each sitting will keep you informed on this point. The treatment must be continued as long as any improvement results from it, or until its uselessness has been clearly demonstrated.

I employ practically the same method in the treatment of dystrophia musc. progress., as, in spite of the constantly negative condition of the cord, I consider it to be by no means disproved that we may have to do with a central tropho-neurosis, and as the possibility, at least, of influencing favourably the peripheral nutritive disturbance in the muscles by electrical irritation of the central trophic apparatus cannot be denied.

An exclusively *faradic* treatment of the disease (either according to Duchenne's method with local faradisation of all affected muscles, or more effectually with general faradisation) will only be resorted to when no galvanic current is attainable. The employment of the 'diplegic irritation' (p. 222 et seq.) has not proved a curative method in progressive muscular atrophy.

The galvanic treatment of *amyotrophic lateral sclerosis*, which has an undeniable relationship to progressive muscular atrophy, and is characterised by a contemporaneous sclerosis of the pyramidal tracts (symptoms of spastic spinal paralysis), is to be carried out essentially after the same principles, with special regard to the funicular degeneration, which demands the influencing of the whole spinal cord. In this disease partial RD is found more or less distinctly in the upper atrophic extremities, but no noteworthy alteration in the lower, which are paretic and not atrophic. The prognosis of this affection appears to be as unfavourable as that of progressive muscular atrophy.

11. In *acute ascending paralysis*, a form which is not yet differentiated with complete certainty either clinically or anatomically, very good effects have been seen from the employment of the electric current in the period of convalescence. Complete integrity of the electrical irritability in all directions is characteristic of this form of disease, at least in its typical cases; but its relations to the ascending form of subacute anterior poliomyelitis have yet to be firmly established.

It is to be considered whether the use of the electric current should not be tried in the early stages of the disease, so long as it is progressive. *A priori* this appears to me justifiable, for we have to do only with impalpable nutritive disturbances, and for such the katalytic action of the current may be of value. I would, therefore, try the application of moderately strong stabile currents along the whole spinal column daily or even twice a day for three or five minutes.

12. *The secondary degenerations of the spinal cord* have seldom been the subject of electrical treatment. Much cannot, indeed, be expected from it so long as the fundamental disease

continues. Such a treatment will scarcely be thought of for *ascending* secondary degenerations, as we cannot, as a rule, diagnose them, but at the most conjecture their existence, because they give rise to symptoms which are not in any way known to us.

But it is otherwise with the *descending* secondary degenerations of the pyramidal tracts, especially in brain diseases (hæmorrhage, softening, &c.) It is pretty generally assumed that this degeneration has a certain influence on the character of the disease, that it causes the increase in the tendon reactions and the subsequent paralytic contractions; and this latter is certainly often a hindrance to the improvement or the re-establishment of the motility. In many cases, therefore, especially where the primary affection has begun to improve and to pass away, the removal of the secondary degenerations of the disease may well be of service. And for such cases treatment with the galvanic current is chiefly to be commended. The method is the same as for all funicular degenerations of the spinal cord: I am in the habit of trying first a stabile, long-continued action of the anode on the whole extent of the cord, the kathode being on the cervical sympathetic meanwhile; then, in older cases, the additional action of the kathode (exactly as in tabes). Besides this the treatment of the primary disease must not of course be neglected.

III. *DISEASES OF THE PERIPHERAL NERVES.*

Literature.—W. Erb: 'Handbuch d. Krankh. d. peripher. Nerven,' v. Ziemssen's *Handb. d. spec. Pathol.*, xii. 1, 1874; 2nd edit. 1876.—R. Remak: 'Med. Centralzeitung,' 1860, No. 21.—'Oesterr. Zeitschr. f. prakt. Heilk.,' 1860, Nos. 45 and 48.—'Applications du Courant Constant, etc.,' p. 15, 1865. —Bärwinkel: 'Zur elektrotherap. Casuistik,' *Arch. d. Heilk.*, ix. pp. 338, 458, 1868.—'Neuropathol. Beiträge,' *Deutsch. Arch. f. klin. Med.*, xvi. p. 186, 1875.—Althaus: 'Neuritis des Plexus brachialis,' *Deutsch. Arch. f. klin. Med.*, x. p. 189, 1872.—Franz Fischer: 'Zwei Fälle von Neuritis,' *Berl. klin. Woch.*, 1875, No. 33.—'Zur Lehre von den Lähmungen des N. radialis,' *Deutsch. Arch. f. klin. Med.*, xvii. p. 392, 1876.—A. Kast: 'Beitr. z. Lehre von d. Neuritis,' VI. 'Wandervers. südwestdeutsch. Neurologen u. Irrenärzte,' *Arch. f. Psych. u. Nerv.*, xii. 1881.—E. Remak: 'Zur Pathol. u. Elektrother. d. Drucklähmungen d. N. radialis,' *Deutsch. Zeitschr. f. prakt. Med.*, 1878, No. 27.—Leber: 'Ueber hereditäre und congenital angelegte Sehnervenleiden,' *Arch. f. Ophthalmol.*, xvii. 2, p. 267, 1873.—Donald Fraser: 'Contribut. to Electrotherap.'—'Case of Amblyopia,' *Glasg. Med. Journ.*, Feb. 1872.

See also the literature referred to in the following lectures in connection with paralyses, neuralgias, anæsthesia, diseases of the organs of special sense, &c., and the different manuals and text books of nervous diseases.

LECTURE XXI.

Introduction—Important Effects of the Current in Diseases of the Peripheral Nerves—Practical Experiences—Cases—Technique and Method of the Electrical Treatment—Individual Forms of Disease—Neuritis—Hæmorrhage and Disturbances of Circulation—Slight Mechanical and Traumatic Lesions—Severe Traumatic Lesions—Degenerative Atrophy of the Nerves—Functional Disturbances—Symptomatic Treatment—Electrodiagnostic Remarks.

Diseases and functional disorders of the peripheral nerves and nerve-muscle regions have been so frequently the subject of electrotherapeutical experiment that one would not be wrong in saying that electrotherapy has been in great part developed by these forms of disease, more so when it is remembered that many affections whose sensory and motor symptoms have appeared local and peripheral have been considered as peripheral lesions, or at least have been treated exclusively as such. This holds good for a considerable number of paralyses, cramps, atrophies, neuralgias, and other affections of a similar nature.

It is precisely with regard to those functional disorders, of whose delicate pathological processes, essential cause and origin, and even precise site, nothing is known, and which have frequently been wrongly attributed to lesions of the peripheral nerves, that electrotherapy was early and especially developed in almost all former books on the subject. The consideration of paralyses, cramps, neuralgias, atrophies, &c., occupies by far the largest space. These matters will not occupy us at present, but will be the subject of a special detailed discussion in the later lectures.

I shall at present treat only of the grosser anatomical lesions and affections of the peripheral nerves, which are undoubtedly of a local nature, quite independently of their individual symptoms (such as cramp or paralysis, neuralgia or anæsthesia, &c.), which symptoms depend only on the accidental seat of these lesions in the sensory, motor, vasomotor, or mixed nerves. We can only at present refer in passing to the finer molecular nutritive alterations, the nature of which has not yet been sufficiently defined, but which are frequently the cause of functional disorders, and which give rise more especially to neuralgias, cramps, and sometimes paralysis.

There are only a few forms of disease with which we shall at present have to deal. In the first place, there is inflammation of the peripheral nerves, or neuritis, in its subacute or chronic forms; next the rare and obscure changes in the amount of blood in the nerves, anæmia and hyperæmia; and the still more uncommon hæmorrhage into the nerves. The most important of all are the mechanical and traumatic nerve lesions, from the slightest to the most severe forms, from simple pressure to the most severe contusion, from slow continued compression (such as are caused by cicatrices, exudations, tumours, &c.) to the most pronounced traumatic rupture, tearing, or division of the nerves, and finally, last but not least, degenerative atrophy of the nerves, which is in most cases secondary to peripheral or spinal lesions, but which is occasionally primary, appearing under the form of what has recently been repeatedly described as chronic parenchymatous neuritis. We must not now consider hypertrophy and new formations in the peripheral nerves; in such cases—with the exception of surgical electrolysis—electricity can hardly be employed except for the relief of symptoms.

If, gentlemen, you have kept all our former discussions in mind you will not have far to seek for the experimental and clinical grounds which render it probable that electricity should exercise a favourable influence on diseases of the peripheral nerves. The katalytic effects of the current are the most important, and have perhaps the most comprehensive sphere of action, due to their influence on the circulation and nutrition and on inflammation and its sequelæ, which can be detected with facility and certainty, because you have generally to do with superficial and easily reached foci of disease. To the same category belong the effects on cicatricial tissue, cirrhosis, and degenerations of the nerves; the actions on absorption of extravasations and exudations into the nerves and nerve sheaths; and the influence on those molecular or nutritive disorders which can be produced as a result of slight pressure or of moderate compression. In all these conditions the katalytic action of the current may be useful.

Furthermore those effects on the vasomotor system which can undoubtedly be produced may be invoked in hyperæmia and anæmia, when it is necessary that the circulation should be improved, the nutrition stimulated, or degenerative atrophy of the nerves contended with. Perhaps also the irritating and modifying influences of the current may here find a place, inasmuch as, when they are applied to the trophic paths and centres, local nutrition disturbances are benefited. At all events this method may be utilised in many functional disorders (molecular, nutritive) which in this section need only be referred to in passing.

Practical experience to prove all these results is not wanting, but, owing to their nature, complete demonstration of the effects in the above-named diseases cannot be always offered. When we have to do with serious organic lesions, cicatrices, degenerative atrophies, &c., rapid effects are not to be expected, but, on the other hand, one frequently sees them in neuritis, and still more often, perhaps, in those less serious disorders which lay the foundation of so many peripheral neuralgias. Permit me in the first place to cite some examples.

36. *Personal Observation. Chronic Neuritis of the Median Nerve.*—A woman, aged 40 years, has suffered for more than a year and a quarter from neuritis of the median nerve above the right wrist, which supervened during childbirth. It began with numbness in the first four fingers, then pains in the same region, which gradually so increased in severity that the patient was deprived of sleep. The median nerve above the wrist is felt as a thickened, swollen, spindle-shaped cord, and is tender on pressure. There is also pain and formication in the entire distribution of the nerve and trophic disturbances of the skin in the same region. The pain is localised, of a stinging and burning character, and, although continuous, accompanied with occasional exacerbations, radiating, when the paroxysms are severe, to the elbow and shoulder. There is no anæsthesia. The motility of the thumb is not impaired to any extent, but the hand becomes readily fatigued on exertion. *Faradic and galvanic excitability* of the nerve somewhat augmented. Galvanic treatment: Stabile application of the anode to the nerve above the wrist and in front of the elbow joint. Result: After the first sitting several hours' relief, and after the second considerable improvement. Each subsequent application was followed by great amelioration, which lasted till night-time. Sleep was much sounder, so that after the tenth sitting the patient slept through the entire night. The feeling in the hand was now more natural, its utility improved, and the pain much diminished in intensity and limited in extent. Subsequently the swelling of the nerve continued to diminish. After the seventieth sitting there was complete recovery. The pain had wholly ceased; no difference could be detected in the size of the median nerves, there was no longer any increase of the electric excitability, and the vasomotor and trophic disturbances of the skin and nails had disappeared.

37. *Personal Observation. Chronic Neuritis Nodosa (Neuroma ?) of the Ulnar Nerve.*—An engineer, aged 25 years, had 20 years ago received a dislocation of the right elbow joint, which had recovered, leaving slight deformity but complete usefulness of the limb. For the last eight years he has suffered from formication in the little finger of the right hand after prolonged writing or drawing (the result of mechanical irritation of the ulnar nerve by the dislocated

internal condyle). For two years there has been weakness and wasting of some of the small muscles of the hand. For the past twelve months has complained of a furry and numb sensation in the little and a deep-seated boring pain in the third finger. Forcible bending of the forearm causes pain in the ulnar nerve. Present condition: The entire hypothenar region of the right hand, the adductor pollicis brevis, and most of the interossei muscles are completely paralysed and atrophied; on the other hand the flexor carpi ulnaris, the flexors of the fingers, and the other muscles are normal. Complete RD in the paralysed muscles. Sensibility in the distribution of the ulnar nerve somewhat diminished, but not wholly abolished. There is slight deformity of the elbow joint, and at the internal condyle of the humerus the ulnar nerve is felt very distinctly and there presents a marked spindle-shaped thickening about the size of a bean. Above and below this the nerve is freely movable. Galvanic treatment: The stabile anode on this swelling, and the kathode is placed alternately above and below it with a few voltaic alternatives, then a labile application of the kathode to the distribution of the ulnar nerve (the anode remaining on the swelling). After five sittings the sensibility of the little finger was improved; the patient can now voluntarily contract the flexor minimi digiti brevis, which he could not do before. After 15 sittings, constant and progressive amelioration. The movements of the hypothenar muscles, the adductor brevis pollicis, and most of the interossei (with the exception of that of the third finger) have returned and can be performed with ordinary facility. The faradic excitability has returned to the ulnar nerve above the wrist, but not to the muscles. The feeling of numbness is markedly diminished. The swelling on the ulnar nerve remains unchanged. The patient was discharged and improvement continued afterwards to increase.

38. *Personal Observation. Neuritis of the Brachial Plexus? Combined Shoulder-Arm Paralysis* (Erb).—A man, 52 years of age, was seized 5 weeks ago with pain and stiffness in the left side of the neck; afterwards the pain extended to the shoulder and arm, accompanied with paræsthesia in the thumb and index finger and progressive weakness and debility of the arm. The pain, at first severe, afterwards gradually diminished, leaving the paralysis unchanged. Examination demonstrates complete paralysis and extreme wasting of the deltoid, biceps, brachialis internus, and supinator longus muscles. The supinator brevis also appears weak; all the other muscles of the left upper extremity are normal. Tactile sensation is somewhat blunted in the thumb and forefinger; otherwise the sensibility is

normal. In the left supraclavicular fossa there are some tender spots on pressure; the muscles also are painful to the touch. The electric excitability appears slightly diminished. Galvanic treatment: Stabile anode to the brachial plexus, galvanisation of the sympathetic, and a descending labile current through the paralysed nerves and muscles. After 5 sittings there was some contraction of the biceps. After 7 sittings the patient could bend the forearm. After 10 sittings, traces of contraction in the deltoid and supinator longus. After 15 sittings the patient can again touch his head. After 35 sittings, complete recovery, the electrical excitability being again normal.

39. *Observation by R. Remak. Paralysis of the Deltoid. Neuritis of the Brachial Plexus.*—A man, 31 years old, has suffered from rheumatism of the three large joints of the right arm for three months. Two months ago there appeared complete paralysis of the right deltoid, which resisted all therapeutic measures for its relief (faradism, blisters). The shoulder joint is still somewhat tender and the paralysis of the deltoid nearly complete. On pressure over the brachial plexus there is a distinct painful swelling, especially at that part from which the circumflex nerve takes its origin. The labile application of the kathode to the muscle has no immediate effect, but the stabile influence of the anode on the painful point of the plexus (for 2 or 3 minutes) enables the patient immediately to raise his arm to a vertical position. Afterwards the swelling of the brachial plexus appeared less painful. Two further applications of the current completed the recovery.

40. *Personal Observation. Traumatic Paralysis of the Left Arm (from Dislocation of the Shoulder).*—A man, aged 63 years, on October 23, 1869, dislocated his left shoulder. Paralysis of the arm immediately ensued. The reduction of the injury was effected without difficulty. At first there was intense anæsthesia, which is now somewhat improved. On February 23, 1870, complete paralysis of the entire left forearm and hand (flexors, extensors, supinators, &c.), and in the upper arm the triceps is also nearly completely paralysed. Complete RD in the paralysed and atrophied muscles. Sensibility in the hand and radial side of the forearm diminished. Galvanic treatment: Stabile current through the shoulder joint, the anode being placed in the axilla; then a kathodal labile current through the nerves and muscles. In 3 days only, distinct relief, the motility of the biceps being improved. On March 3 during the application of the current there occurred slight waving movements in the muscles of the forearms (flexor carpi radialis and flexor

communis digitorum). At the reversal of the current these muscles contract with the application of kathode, and also when the nerve is stimulated with it (rapid contraction). While the kathode is in the axilla there occur slight voluntary contractions of the above-mentioned muscles. March 5. Distinct improvement in the motility of the flexors of the forearm. March 29. When the stabile anode is in the axilla there occur slight wavy movements in the extensor muscles of the forearm, as well as traces of contraction when an attempt is made voluntarily to contract them. This improved motility visibly increased during the following days. The appearance of the arm and hand, which was before swollen, cyanotic, and cold, has become much improved. April 6. The patient discontinued treatment; markedly improved. June. The amelioration has still further advanced.

41. *Personal Observation. Paralysis of the Right Radial Nerve (Traumatic Neuritis?).*—A man, 45 years old, was on December 26, 1874, seized with sudden paralysis of the right radial nerve, accompanied with a giddy sensation. For this no cause could be determined. In addition there was a sensation of formication in the radial side of the hand. Faradisation of the forearm proved useless. Condition on February 15, 1875: There was paralysis of the entire radial distribution of the forearm. No pathological change was found in the radial nerve itself in the forearm, and the sensibility was undisturbed. Electrical investigation shows the site of the lesion to be in that region where the nerve bends round the elbow joint (interruption of conduction). Below this partial RD exists in the nerve-muscle distribution; above, absolutely no contraction can be obtained through the nerve. Galvanic treatment: Anode on the neck, and stabile kathode over the seat of lesion (with a few changes in polarity), then labile through the nerves and muscles. On the following day there was distinct improvement, and the hand can be raised almost to a horizontal position. After the fourth application marked amelioration, especially in the supinator longus and in the extensores radiales and digitorum. Now stimulation at the seat of lesion causes feeble contractions of the muscles, and after each application the condition is improved. After 22 sittings the patient is discharged, cured, the electrical excitability being almost normal.

42. *Observation by Moritz Meyer. Neuralgia (Neuritis?) of the Brachial Plexus.*—A girl, 14 years old, has suffered for 9 months from pain in the fourth interosseous space of the right hand, which gradually extended in the course of the radial nerve throughout the upper and fore arm as far as the posterior edge of the deltoid muscle.

At the outer part of the brachial plexus there is a small thickened spot, painful on pressure. The application of the stabile anode to this spot brings immediate relief. Recovery after 17 sittings.

43. *Observation by Moritz Meyer. Neuralgia (Neuritis?) of the Ulnar Nerve.*—A girl, 19 years old, has, in consequence of tight bandaging, suffered from pain in the fourth metacarpal space and along the course of the cutaneous branch of the ulnar nerve to the elbow and right side of the neck. On this account she has been unable to use the arm. Great tenderness on pressure at the lower part of the brachial plexus (neuritis ascendens?) Application of the anode (10 elements) to this region effects much improvement in 4 sittings. After 20 sittings the patient can play the piano for from half an hour to an hour, but the last traces of pain did not disappear until after 54 sittings.

44. *Personal Observation. Neuralgia of the Right Occipital and Trigeminal Nerves (Neuritis ?).*—A compositor, 24 years old, suffered in April 1872 from violent right supra- and infra-orbital neuralgia. This was cured by 4 sittings of application of the stabile anode. June 1872. Neuralgia in both trigeminal (third branches) and in the occipital nerves, which was cured in a few days by the stabile application of the anode. August 1883. For 14 days has suffered pain in the right ear, in the right side of the face (in all three branches of the trigeminus), and in the right half of the occiput and scalp. Acute tearing pains, especially in the afternoon for a couple of hours. At the same time a feeling of numbness at the back of the head and in the right side of the face, and during the paroxysms of pain there was great salivation. No painful spot in the face, but one could certainly be detected in the course of the great occipital nerve. Throughout the entire painful region there is a moderate amount of anæsthesia. Galvanic treatment: The stabile anode, gradually increased and diminished in front of the ear and occiput, caused little improvement in 5 sittings. (Ordered quinine and morphia.) After 10 sittings the patient was discharged, cured.

45. *Personal Observation. Left Sciatica; Anæsthesia (Neuritis ?).*—A railway porter, aged 43 years, suffered four weeks ago, after a cold, from severe pain in the back, which disappeared after a few vapour baths. After this he was attacked with violent pain in the left leg and foot, which lasted for two weeks. For the last 8 days the patient has been tolerably free from pain, but has experienced a numb and furry sensation in the entire left leg, from the gluteal region down the entire course of the sciatic nerve. The limb was very feeble, so that the patient could only walk with the aid of a stick. Present

condition: Limping gait; limb very feeble, but all individual movements possible. Sensibility to touch and pain in the posterior and lateral surface of the thigh and in the whole leg diminished, but not wholly abolished. Considerable sensation of cold in the left leg, which is of a lower temperature than the other. No other objective symptoms. Galvanic treatment: 20 to 24 cells, descending stabile, with a few interruptions. After 2 sittings improvement; sensibility in the leg returned, and only in the foot and thigh still lowered. After 8 sittings considerable amelioration; the patient walking much more easily, although the sensibility is not yet quite normal. During the following days a pain reappeared in the sciatic nerve, especially at night. After 15 sittings the pain and numbness had totally disappeared, and the sensibility to objective examination was normal. The patient was discharged cured, and has continued well since.

46. *Personal Observation. Neuralgia of the Right Supra-orbital Nerve.*—A glove maker, 26 years old, has suffered for the last five days from severe neuralgic pain in the right supra-orbital nerve, lasting during the day, but permitting rest during the night. A very pronounced painful point at the supra-orbital foramen. The nerve throughout its entire extent tender on pressure. No sensory disturbance. Galvanic treatment: A gradually increasing and diminishing current with 8 cells, the stabile anode being on the nerve trunk and the kathode on the left hand. The pain ceased immediately afterwards. Cured after two further sittings. After the first application the painful point had disappeared.

47. *Personal Observation. Neuralgia of the Superficial Branch of the Left Radial Nerve.*—A maid servant, aged 33 years, has for 8 days suffered from violent pains, limited to the region of distribution of and along the left superficial radial nerve, beginning at 4 o'clock in the afternoon and lasting throughout the entire night. The movements of the hand and fingers are performed with difficulty during the paroxysms. For the last 6 days numbness in the hand at the region of distribution of the nerve, on which there was a painful point. Galvanic treatment: Descending stabile current through the nerves (3 to 4 minutes). The pain did not return after the first application, but there were slight indications of it, which after two further sittings disappeared.

48. *Personal Observation. Neuralgia of the Trigeminal Nerve. Herpes labialis.*—A maid servant, 24 years old, has been ill for the last 3 days with vomiting, headache, and some fever. Since yesterday has suffered from pain, limited to the left side of the face, which is very severe, especially in the cheek, forehead, and radiating through

both dental arches. It occurs five or six times daily in paroxysms of from 30 to 60 minutes' duration. There is a painful point at the supra- and infra-orbital foramina, and herpes on the left lower lip. March 21. Galvanic treatment: A stabile current applied, with a few interruptions, from the mastoid fossa to the supra- and infra-orbital and mental foramina. Immediately afterwards great relief. March 22. Since yesterday there have been two moderate paroxysms of pain; the painful point is less tender. March 23. Yesterday there was no attack whatever, but to-day two slight ones, especially in the frontal nerve, which was more particularly treated. March 24. This morning there was one slight attack. The herpes is drying up and the painful point cannot now be detected. March 26. Discharged cured.

49. *Observation by Leber. Retrobulbar Optic Neuritis.*—A young man 19 years old has for the last 8 months suffered from a persistent attack of this disease, which has resisted all treatment. During galvanisation of the sympathetic there was striking and very rapid improvement and almost complete restoration of sight in one eye (A on the superior ganglion). The application of the current transversely through the temples proved ineffectual. After each sitting an improvement in sight could be demonstrated.

50. *Observation by Donald Fraser. White Atrophy of the Optic Nerve.*—A man 59 years old has suffered from diminution in acuteness of vision for the last 5 years, more marked during the past 9 months. September 1871. R. eye, Snellen 20 at 4 inches; l. eye, at 8 inches. Ophthalmoscopic appearances: The external two-thirds of the optic nerve are white and shining, the inner third hyperæmic; the veins tortuous and dilated; the arteries diminished in number and calibre; white streaks along some of the vessels. No other form of illness. Diagnosis: Primary degeneration of the optic nerve, treated without result for 4 weeks with mercury and iodine. October 1871. Snellen 20 with both eyes at 7½ inches. Galvanisation with 6 cells for 20 seconds through the temples. Immediately afterwards Snellen 20 could be had at 10 inches. Treatment: Application of the current transversely and longitudinally through the head. Progressive improvement took place, and at the end of 3 months Snellen 5½ could be had with the same ease as formerly was Snellen 20. The beneficial results are daily perceptible after each application of the galvanism. January 1872. Distinct improvement also in the ophthalmoscopic appearances; the arteries are wider and the veins narrower and less tortuous. The amelioration still continues.

Just as in diseases of the brain and of the spinal cord so here we must infer from therapeutical experience, and from our general electrotherapeutical views, that the galvanic current must be employed principally and almost exclusively in diseases of the peripheral nerves, so far as we have to aim at producing katalytic and vasomotor effects; although in order to obtain stimulating and modifying results, and to compensate the more minute molecular nutritive disturbances, the faradic current may be employed in the same way as the galvanic.

In most cases the treatment of the diseased part should, of course, be as direct as possible, but still an indirect treatment need not be omitted, as it is quite possible to set vasomotor and trophic influences in action from the upper portion of the peripheral nerves, from the sympathetic tract (cervical sympathetic in optic neuritis), or even from the spinal cord and its centres. Finally, in many cases a reflex action from the skin (faradic brush, &c.) may not be entirely useless, especially in the more functional and specially molecular disturbances (e.g. neuralgias). In all cases in which a direct action on the diseased nerve cannot be easily carried out—as, for example, in the nerves at the base of the skull, the optic nerve, &c. —you must avail yourselves chiefly of this indirect katalytic action.

You may adopt the following methods of application for the special forms of peripheral nervous diseases.

In *neuritis* the stabile action of the anode has been held to be the best, at least in all recent cases, the kathode being placed either exactly opposite or on some indifferent point, such as the sternum. It appears to me more advisable, however, to apply the kathode, where it is possible, to a more central part of the diseased nerve, or to the corresponding region of the cord, the cervical or lumbar enlargement, in order to influence simultaneously the vasomotor (and trophic?) nerves and centres. The currents must be of moderate strength (25° to 40° N defl. with 150 GR, about 4 to 10 ma.), and must be allowed to act from 2 to 5 or 10 minutes; the result each time will generally indicate the proper length of the sitting.

In older, very chronic cases (e.g. Obs. 37), where connective-tissue induration, cirrhosis, and dryness of the tissue may be surmised, or where advanced degenerative atrophy can be demonstrated, you may employ the anode alternately with the kathode, and the latter perhaps even more often and with greater intensity.

You must employ the same mode of procedure in *hæmorrhage* into the nerve sheaths, which occurs as seldom as it is difficult to recognise. When anæmia or hyperæmia of the peripheral nerves is suspected—you will seldom be able to diagnose it with certainty—the methods of treatment are obvious: action on the vasomotor nerves; in anæmia the energetic stabile action of both poles above the affected spot, or on the cord or the sympathetic; in hyperæmia a shorter, more fugitive action of the kathode on the same place.

In *slight mechanical and traumatic lesions*, causing only molecular change in the nerve fibres, capable of rapid removal, displacement of the sheath, and perhaps also a little disturbance of circulation, there is evidence to prove that a direct action of the galvanic current on the seat of lesion is of service, and that sometimes by means of this agent a distinct improvement even of the paralytic symptoms present may immediately ensue. R. and E. Remak have found this to be particularly the case in the frequent paralysis from pressure of the musculospiral nerve in the upper arm, and I can thoroughly confirm the fact, at least at certain stages in some slight cases of this paralysis. We find that this good effect is specially attained by the stabile action of the kathode of a weak galvanic current; if it is attainable at once the patients can move the muscles voluntarily with much greater ease during the action of the current. At all events this method, combined, in suitable cases, with the action of the anode, should be tried first in these and in allied cases, though a further antiparalytic action of the current is thereby by no means excluded. An indirect vasomotor, katalytic action, by means of galvanisation of the nerves above the lesion, may also be tried. Moderate faradic currents may be applied for the same purpose; the reflex influence of dry faradisation with the brush may likewise be resorted to.

In *severe traumatic lesions* the favourable action of the electric current can, of course, only begin when the cause is removed. The latter indication may be fulfilled in the case of cicatrices and the like, by the current itself, owing to its absorbing or katalytic power (vide p. 256); but the treatment of the nerve injury itself, the promotion of reunion between the ends of the divided nerve, is imperative. The seat of lesion must be treated energetically and for a long period with stabile currents, the anode and the kathode successively, though in more cirrhotic conditions you should employ the kathode principally, stabile and labile, even on the central end of the nerve.

In addition to the injury itself, the *degenerative atrophy of the nerves*, always present in such cases, must be treated. Experience teaches that good results are to be expected only when the central trophic influences are not entirely suspended, or at least when they have been restored in part, for you will not succeed in preventing or even in retarding degenerative atrophy in its development even by very early and regular galvanisations or faradisations. Still it is not impossible by these procedures, even before the re-establishment of trophic conduction, to facilitate and hasten the subsequent restoration. But you ought not to expect any substantial result in such cases until the original lesion in the nerve is so far cured that some continuity, however slight, exists between the peripheral and the central portions. In all such cases of *secondary* degenerative atrophy (recognised by RD) the treatment of the seat of lesion itself is the most important, that of the degenerative atrophy being only secondary, and specially indicated when the improvement begins to be distinct. Where we have to do, on the other hand, with a *primary* degenerative atrophy, as in cases of so called parenchymatous chronic neuritis, the treatment of this morbid change must be directly undertaken and may have immediate results.

In both cases it is our aim to combat the further degeneration of the nerve fibres and to hasten their regeneration, and this can be done by means of energetic nutritive influences, and also by means of the regulation and increase of the blood supply. The most serviceable method for this end is the energetic galvanisation of the nerve trunk in its whole extent. The faradic current has much less effect in such cases, if it is of any use at all. I generally let the anode act steadily, to begin with; afterwards I apply the kathode principally, passing it slowly up and down along the nerve trunk, the currents being pretty strong (30° to 50° N defl., 6 to 15 ma.) The time is from one to four minutes daily for each nerve, and the same application may be made to the muscles which are under the influence of the diseased nerve.

The proper time to begin in primary forms is at once, and in secondary forms as soon as we can surmise that trophic conduction has been re-established, sometimes even sooner. It is advisable to begin work as soon as possible upon the central portion of the nerve and the corresponding centre in the cord, in order to promote cure more rapidly in the peripheral portion by stimulation of the vasomotor and trophic nerves and centres.

What in our present knowledge we regard as purely *functional disturbances* of the peripheral nerves (neuralgias, anæsthesiæ, spasms, paralyses, &c.) is to be treated by either current according to the indications present; and according to whether the stimulating or modifying, perhaps also the katalytic and nutritive action of the current is required, you will choose between the faradic and the galvanic current, and the various methods and sites of application. These topics will occupy us more particularly in the following lectures. They stand at the base of what is understood by the symptomatic treatment of disease, which is just as necessary in lesions of peripheral nerves as in those of the brain and spinal cord to supplement the treatment of the diseased part itself. Anæsthesia and paralysis, neuralgias and spasms, peripheral vasomotor and trophic disturbances, &c., are the subjects that come within this domain.

Only a few remarks are necessary with regard to the *electrical excitability* in peripheral nerve lesions. The results of the electrical examination have not the great diagnostic value which was formerly ascribed to them, at least in respect of the seat of the lesion and especially of the distinction between peripheral and central paralysis. You have seen that exactly the same alterations of excitability may occur in spinal diseases as in peripheral; but a distinction between peripheral lesions of the cerebral motor nerves and special cerebral functional disturbances may be possible by means of electrical testing. Electrical examination is often of decided value in determining more particularly the seat of the lesion, if the situation of the arrest of conduction can be accurately localised by it: if, in motor nerves, the excitability is intact below the seat of lesion, but above it apparently lost, then the diseased part may be easily determined; and in the same way if, in sensory nerves, no excentric sensations can be obtained below a certain point, whilst they are well preserved above it. But this is only possible in a very few cases, most often in the nerve trunks of the upper extremities.

As for the rest, every possible alteration of the electrical excitability may occur, as you will remember in the general electrodiagnosis—increase, diminution, partial and complete RD, the two last-named being especially valuable for determining the severity of the lesion and discovering the degree, extent, and stage of the degenerative atrophy in nerve and muscle.

In *neuritis* there is a little rise in the excitability in slight cases, generally followed, later, by a slight fall; but if the disease has caused a more severe lesion of the nerve the various degrees of intensity of RD will be observed, from the slightest partial to the complete form.

In traumatic nerve lesions, as in neuritis, all depends upon the severity of the injury, upon whether the nerve tracts are slightly and temporarily affected, whether their conduction is entirely or imperfectly interrupted, perhaps also upon whether the motor tracts alone or also the trophic at the same time are injured in their powers of conduction. In part of the cases, therefore, the electrical excitability may remain normal, in part it may be simply diminished, and in all severer lesions either partial or complete RD may come on. The latter is, under all circumstances, a sufficient indication of the presence of degenerative atrophy. The most important thing about these results is their prognostic signification, for here, in the peripheral nerve lesions, the rule given before (p. 204) specially holds good: that under the same circumstances—i.e. with the same form and cause of disease—the lesion is more severe and obstinate the greater the alterations of the electrical excitability are and the more complete the occurrence of RD.

IV. PARALYSIS AND ATROPHY.

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LECTURE XXII.

Introduction—Definition and Pathogenesis of Paralysis—Aim and Objects of Electrotherapeutics in Paralysis, and the Methods of their Fulfilment—(*a*) Removal of the Paralysing Cause—(*b*) Removal of the Hindrances to Motor Conduction—Direct and Indirect Methods—Importance of the Reflex Tracts—Methods of Employing the Galvanic and the Faradic Current for this purpose—(*c*) Removal of more Minute or Grosser Nutritive Disturbances in the Motor Tract—(*d*) Restoration of the Normal Condition of the Paralysed Muscles—Treatment of Muscular Atrophy—Results of Electrotherapeutics in Paralysis—Electrodiagnosis of Paralysis—Practical Technical Remarks.

Paralyses of various kinds and in every situation belong to the most frequent forms of disease; the loss of the accustomed mastery over separate parts and movements of the body makes a deep mental impression on those affected, and such an affection more or less interferes with the calling and livelihood of the patient. Paralysis of the arms and hands makes a vast number of industrial and artistic occupations impossible, and may even interfere with mental employment through its disturbing influence on writing. Paralysis of the legs limits the power of locomotion and makes a whole series of callings impracticable; paralysis of the ocular muscles embarrasses or destroys another great number of important functions; paralysis of the muscles of mastication and of deglutition obviously is fraught with the greatest dangers, and even simple facial paralysis is in the highest degree unwelcome, on account of its disfiguring consequences. The interposition of the physician is, therefore, desired oftener and more urgently in these forms of disease than in many others, sometimes much more dangerous to life.

Ever since electrotherapeutics has existed, paralysis of every kind has been one of its chief objects, and it is in connection with this symptom that results have been obtained which have been remarkably evident and tangible. What, indeed, is more important than to exercise upon a paralysed or weakened part an influence which determines muscular contractions, that have remained in abeyance in spite of the utmost exertion of the will, and conjures back again the lost movements of the parts before the astonished eyes of the despairing patients? The inspiring thought of directly stirring up the destroyed functions, of calling them into action by suitable stimulation, of exercising them, and thereby recovering them for the organism, must lead to the employment of that agent which stands far before any other in its action on the motor nerves and the muscles —that is, the electric current. And this has been done over and over again: I should be simply going over the whole history of electrotherapeutics if I were to go further into the history of the electrotherapeutics of paralysis.

Practical results have shown that the idea of employing electricity for paralysis was right at least in the main; countless paralyses have been healed by it, and will be healed daily by it, often with surprising rapidity, often only after long-continued exertions; and no other remedy has won for itself so secure and permanent a place in the therapeutics of paralysis as the electric current.

But in spite of immense experience, in presence of the numerous experiments which have been undertaken to explain it, and although the scientific investigation of electrotherapeutics has concentrated itself on paralysis, we are still not quite clear as to the real nature of the antiparalytic action of electric currents. At all events we can refer only a part of the cures which are being daily effected to simple physical forces which we can understand. It is unnecessary to do more than to hint here that this is in great part the result of our ignorance even of the more minute pathological processes in paralysis.

It seems to me called for, therefore, to go somewhat into the nature and definition of paralysis, into the pathological occurrences which are present or supposed to exist, in order to establish from them what the therapeutical rationale really is, and to which of the current actions with which we are familiar we may appeal in our endeavours.

We may define paralysis as a 'diminution or suspension of the power of exciting the motor nerves and the muscles to their normal function,' or, in other words, 'deficient or abolished muscular contraction with intact power of will.'

This condition may be brought about, first, by disease of the muscles themselves (atrophy, degeneration, suspended irritability from certain poisons, &c.): this is the so called *myopathic paralysis.* But paralysis may, further, be caused by disease of the motor tracts at any part of their course from the muscles to the motor centres of the cerebral cortex, and by disease of these centres themselves ; this is *neuropathic paralysis.* (If the seat of the will is to be found in still higher centres, the lesions of the motor cortical centres also may then be regarded as paralyses in the motor tracts, whilst otherwise they would be contrasted, as *central paralyses*, in the more exact sense of the word, with *paralyses of conduction* ; these latter would then be divided, according to their seat, into peripheral, spinal, and cerebral. This would make no difference in electrotherapeutics; the distinction between myopathic and neuropathic paralysis, and the division of the latter into peripheral, spinal, and cerebral, is quite sufficient for us. The abolition of the will itself—*abulia*—does not belong to the category of paralysis, but comes into the domain of the psychoses, and is to be treated accordingly in a suitable manner, if necessary also with the electric current.)

Such neuropathic paralyses (and they form by far the greatest part of all paralyses) are occasioned by many different causes, which affect the power of generating and of conducting impulses in the cells and nerve fibres—viz. by inflammation, degeneration and atrophy, hæmorrhage, anæmia and hyperæmia, but perhaps most often by simple mechanical influences, such as compression, contusion, rupture, incision, and the like. They may likewise be caused by less palpable changes, not very obvious anatomically, by the action of certain poisonous substances, by over-exertion and exhaustion, by cold, hysteria, and so forth—in short, by the so called 'functional' disturbances, the nature of which we do not yet know; we are not even always able to localise their exact seat, for while some of the affections are circumscribed there are others which are more diffuse and spread over a great part of the nerve tract.

But we have not yet exhausted all the symptoms in paralysis which must become the object of our therapeutical endeavours ; in the paralysed parts—the nerves and muscles—certain changes may develope themselves in time. These are frequently only of a *simple nutritive* or molecular nature, and may assume the form of diminished conductivity and excitability, or, at most, of simple wasting, and are caused partly by the inactivity, partly no doubt by the interference with certain trophic stimuli; but sometimes they are of a much more serious character—that of *degenerative atrophy* of the nerves and muscles, going on to excessive connective-tissue cirrhosis—important changes which are quite inevitable in many forms of paralysis.

The object of electrical treatment, then, in all these pathological processes, is this: *the restoration of the normal influence of the will on the muscles*; in other words, this usually consists in the restoration of conductivity in the motor nerve tracts, whether it be in any one part or in their whole length. In a smaller number of cases we have to deal with the restoration of the irritability, the contractile power, and the nutrition of the muscles; and as a more general indication, we must never fail to attempt the removal of the changes set up in nerves and muscles by the paralysis.

Let us see what special tasks are thus set before us, and with what means and methods of electrotherapeutics we can accomplish them.

(*a*) The first and the most important duty that meets us is the *removal of the paralysing cause*, i.e. the essential local lesion at the diseased part of the motor tract. Only a part of these forms of disease is accessible to electrotherapeutics, such as the various diseases of the brain, the spinal cord, and the peripheral nerves, which I have described in Lectures XVI. to XX.; if these have caused the paralysis they must be treated directly and at once, in the manner you already know, and you will remember that the galvanic current, with its katalytic action, is to be preferred for this purpose.

Some of these paralysing causes cannot be reached by electricity, but must be treated in other ways—such as internal remedies, surgical or hydropathic measures, &c.

Finally, there remains a set of cases in which we do not yet know accurately the nature and the seat of the paralysing affection, as, for example, hysteria, various toxic affections, many paralyses after acute diseases, &c. In such cases this causal treatment must either be given up or must be applied experimentally to all the organs which might be affected, according to a systematic plan; your pathological views and your diagnosis must govern you in treating whether only the peripheral nerves or also the spinal cord and the brain, or in acting at all three localities successively.

(*b*) But along with the correct fulfilment of this causal indication there is often a second duty to be discharged, viz. the removal of the hindrances which arrest the transmission of impulses at the seat of lesion. This indication is not always fulfilled by the accomplishment of the former task; and in all cases where the causal lesion cannot be found and accurately localised, where the causal treatment does not have the desired effect quickly and completely, or, as is frequently the case, requires to be further supported, this second indication must be fulfilled, and with this the *direct antiparalytic action* of the electric current begins. With reference to this point we must in the first place dwell upon the exciting action of our remedy. A hindrance in the motor conduction, which cannot be overcome by the will, may perhaps be conquered by a stronger, artificial stimulation, and the way thus made clear for voluntary excitation. Hence, if we allow the electric irritation to act energetically above the seat of lesion the hindrance may perhaps be in this way removed. A very fair comparison would be that of a water pipe in which the current is stopped by some hindrance (a mass of mud, a solid body, or the like), which weakens or completely prevents the flow. The simplest remedy for this is to wash away the hindrance by a stronger current of water, under higher pressure, and so to make the course free again; and this may be done with one strong impulse (of which we sometimes have an analogous experience in the electrotherapeutics of paralysis), or by repeated currents of such a strength as shall be sufficient to wash away the obstruction gradually (as in prolonged treatment of paralysis). I would refer, further, to the well-known fact that the obstruction in a motor tract is diminished by its more frequent use (influence of exercise), and we may bring this about artificially by repeated electric excitation. It is sometimes possible in this way to induce a continuance of the exciting process; and if this has once been accomplished the stimulation of the will may gradually begin to act and the paralysis gradually to disappear.

It is evident that for this purpose the application of the stimulus centrally to the seat of lesion is absolutely necessary (fig. 35). In order to remove an obstruction *a* in the course of a motor nerve *n*, so that the centrifugal voluntary stimulation may again reach undisturbed to the muscle *m*, the electric excitation *e* must start from above the lesion *a*. The rationale is clear, and the plan may well be carried out in many peripheral paralyses, especially in the extremities, the arm and leg; still it is not always practicable even in peripheral paralyses—as, for example, in paralysis of the facial nerve inside the Fallopian canal, of the cerebral nerves at the base of the skull, or in lesions of the cauda equina, &c. In such cases our purpose could not be realised at all if we were not fortunately

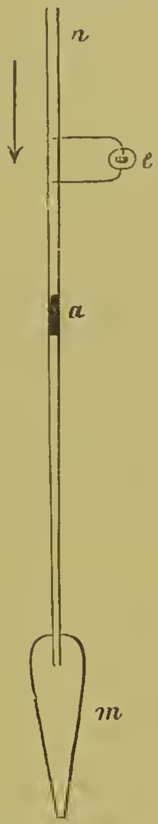

FIG. 35.—Diagram representing *a motor paralysis*. *n*, motor path; *m*, the muscle; *a*, seat of lesion in the course of the motor impulse; *e*, electrical excitation (centrally to the lesion).

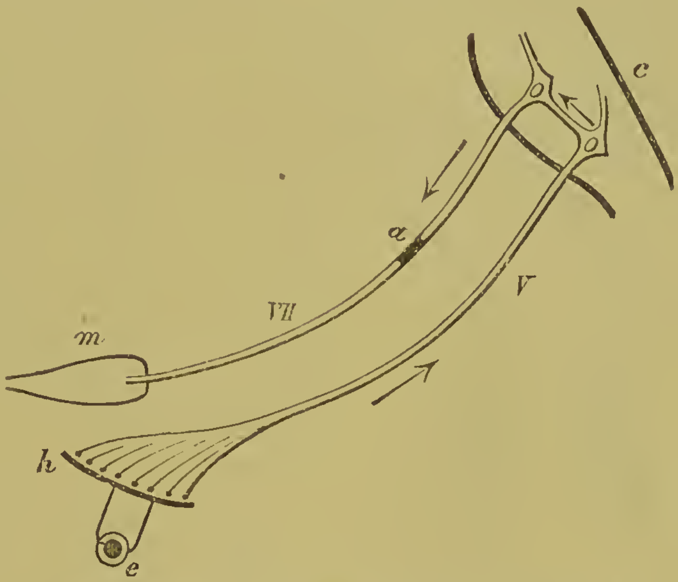

FIG. 36.—Diagram representing *a peripheral facial paralysis*, and showing the method of reflex electrical treatment from the trigeminus. VII, facial nerve; V, trigeminus; *m*, the muscle; *h*, the skin and peripheral termination of trigeminus; *c*, central organ (medulla oblongata); *a*, seat of lesion in the facial nerve; *e*, excitation of the skin. The arrows indicate the direction of the current.

in a position to apply the electrical stimulus to the desired spot—central to the lesion—in an *indirect, reflex manner.* In many cases this is very simple, but in many, again, not so easy; still we can generally manage to accomplish our purpose, as the following diagrams will make clear to you.

The matter is very simple if the shortest and most frequently traversed reflex circuit is intact, as, for example, in peripheral facial paralysis, if the trigeminus remains uninjured (fig. 36). If in the facial nerve VII an obstruction *a* is present, say at its entrance into the Fallopian canal, we cannot apply the electric current with the necessary strength above the lesion; but if we excite with the electric current *e* the portion of the skin of the face *h* supplied by the trigeminus V, or the trunk or individual branches of the nerve, a centripetal excitation will be set up, which will be transferred in the central organ *c*, by the shortest reflex circuit, on to the trunk of the facial, and act as a centrifugal stimulation on the obstruction, with the same result as if we had applied the electrical stimulus centrally to the point *a*.

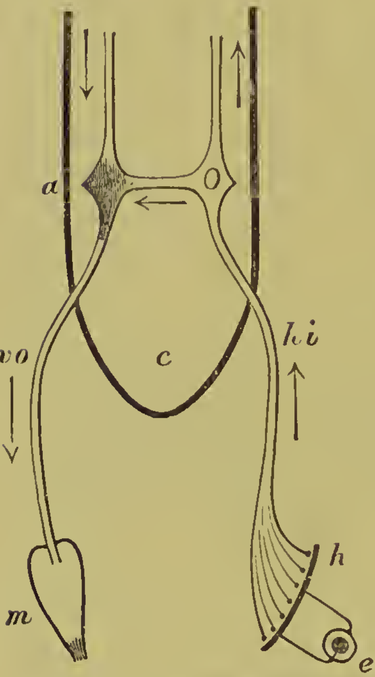

FIG. 37.—Diagram representing a *central paralysis*, e.g. an infantile spinal paralysis. *c*, nerve centre; *m*, the muscle; *h*, the skin; *e*, point of electrical excitation; *hi*, path of sensory impulses and posterior nerve roots; *vo*, motor paths and anterior roots; *a*, seat of lesion, situated within the reflex circuit, *hcm*.

Similar conditions obtain in infantile paralysis, for example, where the obstruction lies in the reflex circuit itself, but where the sensibility of the skin is perfectly intact. A central stimulation of the motor tract is likewise impossible, but reflex excitation can seize upon a more favourable spot, in order to overcome the obstruction, as the annexed diagram (fig. 37) will show you without further explanation.

But the case becomes more difficult if we have to do with *paralysis of peripheral mixed nerves*, where the sensory tract is also interrupted, as at *a* in fig. 38. An excitation from the skin at *h* will have no effect on the motor paralysis; it is interrupted at the obstruction *a*, and will be unable to set up any reflex excitation in the motor tract; in order to do that we must employ tracts situated farther forwards or backwards for the reflex excitation (or even those on the other side of the body at the same level); in our diagram (fig. 38), for example, the tract h', which is in indirect, reflex connection with m, indicated by the arrows. According to well-known physiological laws, however, this reflex irritation will be considerably weaker than if the natural and shortest reflex circuit had been employed. But something else may be accomplished by the electrical irritation of h; the obstruction of the sensory tract may be overcome, and the way made clear, and so the shortest reflex circuit for the centrifugal stimulation of the tract Rm be opened. A direct action upon the paralysis is thus made possible. Exactly the same thing comes to pass if—as so often happens—the conduction of sensory impressions is restored sooner than that of motor; the sensory tract is then immediately made use of for reflex excitation. I have no doubt that a part of the cures which are effected by faradic and galvanic treatment *below* the seat of lesion depends

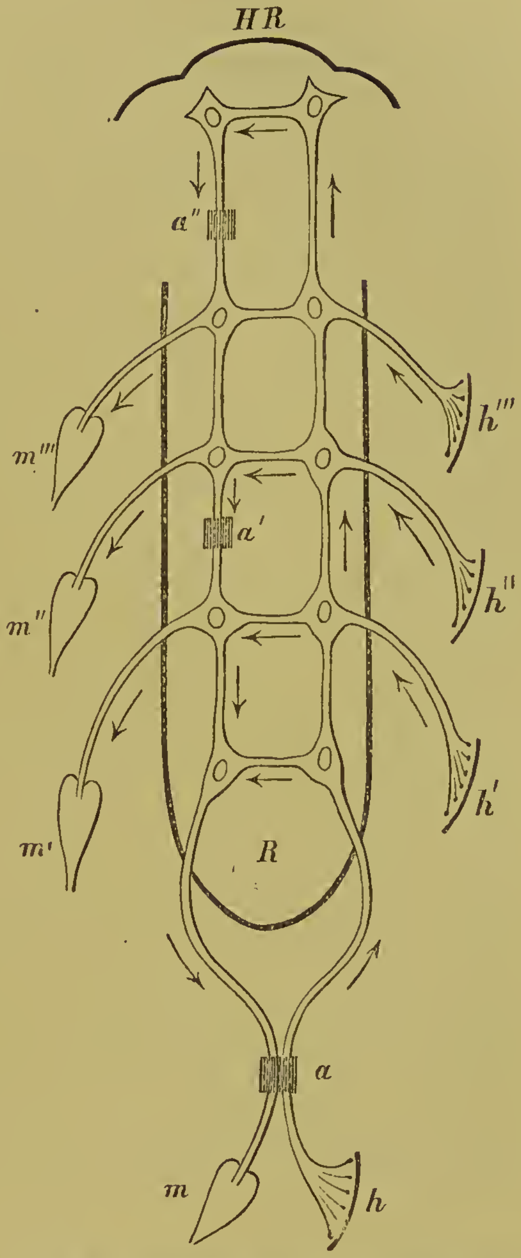

Fig. 38.—Diagram to show the various channels of reflex action available for the treatment of *central and peripheral paralyses.* r, spinal cord; hr, cerebral cortex; m, m', m'', m''', motor paths and muscles; h, h', h'', h''', sensory paths and skin; a, lesion of a mixed peripheral nerve; a', lesion in the path of spinal motor impulses; a'', lesion in the path of cerebral motor impulses. For further particulars see text.

upon a procedure very much like that indicated by this diagram.

But the matter becomes still more complicated and difficult in central paralyses; if the nearest and shortest reflex circuit lies below the seat of lesion (as in fig. 38 the circuit $h'\text{R}m'$, if the lesion is at a'), then its excitation has of course no direct influence at all on the diseased spot, and consequently none on the paralysis, especially if the sensory conduction is obstructed at the same time at the level of a'. From this it follows that spinal and cerebral paralyses, in which the reflexes are normal or increased, cannot be affected at all, or only with difficulty, in this reflex manner; it can only be brought about by the reflex stimulation—the sensory conduction being normal—acting centrifugally upon a in a roundabout way, or from a distant sensory tract; and for this purpose the reflex tracts lying more forward are always to be employed. As there are certainly reflexes given off from the cerebral cortex, which originate perhaps in the motor cortical centres, or even beyond (there is indeed little known about them, and they are not easily accessible for physiological study, as the reflex circuits situated below cannot easily be excluded), it is possible to make use of reflex irritation, proceeding from the centre, for paralysis in any situation (as, for example, for a lesion a'' in our diagram, which might involve the region of the internal capsule), and to do so by means of electric irritation of any part of the skin on the paralysed side. From this it comes to pass that the sensory conduction to the cortex of the brain is perfectly intact in many of the paralyses which we are considering here (from cerebral hæmorrhage, &c.) Also, this may doubtless serve to explain a part of the beneficial results of faradisation and galvanisation in central, and especially in cerebral, paralyses; and the assertions of Vulpian and Rumpf that the motor paralysis, the speech, &c., may be improved, in hemiplegia with anæsthesia, by circumscribed faradic brushing of the skin of the forearm, agree with this very satisfactorily.

In order to attain these stimulating effects you may employ the various methods, with both kinds of current, which have already been described in the General Part (p. 251). With the *galvanic current* the use of the kathode is to be preferred, on account of its stimulating action and its power of increasing the irritability; it may be employed stabile to begin with, but afterwards more profitably labile, drawn energetically, with a sufficiently strong current, over the portions of nerve and muscle, or of the skin, which are to be stimulated. The contractions which are produced serve as a criterion for the strength of the current; and for central stimulation, where there is of course no contraction, or in non-excitability of the peripheral portion of the nerve, you may select the strength of the current according to its effect on the same or similar healthy nerves. For stronger and repeated stimulations (especially central to the seat of lesion) KC on the proper situations may very profitably be employed. If you need a still stronger irritation, repeated changes of polarity will be the suitable means of obtaining it. During all these proceedings the anode may be placed on the seat of lesion or anywhere central to it (on the plexus, the spinal cord, &c.), or even on some indifferent spot. You will hardly ever employ the anode itself for the purposes which we are now considering. For the irritation of the skin you may use the metallic brush, attached to the kathode; it is, however, very painful, easily produces sores, and has no advantage over the much more convenient faradic brush.

It is generally sufficient to apply the *faradic current* by means of moist electrodes to the affected nerve trunks, in the manner determined by the special case, according to the rules for localised faradisation, in such a way that the application shall be made central to the lesion on the motor tracts and peripheral to it on the sensory. To this may be added faradisation of the skin, either 'general faradisation' with a large, moist, sponge electrode (for this purpose preferably the kathode), or under certain circumstances the faradic brush, partly powerful local faradisation of certain small portions of skin (Vulpian), partly more diffuse farado-cutaneous brushing, in vigorous strokes, with a moderately strong current (Rumpf). In all cases you must be cautious in selecting the strength of the current, which must not be too great, in order to avoid exhaustion of the motor tracts and over-stimulation of the sensory.

It is generally stated that the modifying, and here in particular the excitability-increasing, action of the current may be employed for antiparalytic purposes; this is not quite intelligible to me, because we have to do here chiefly or entirely with the restoration of the conduction, and not with that of the irritability, and we can only find a theoretical basis for this action in so far as that, after all, the conduction in the motor nerve is nothing but the successive irritability of its several sections for a stimulation proceeding from the nearest central section. Here also we must apply the kathode stabile, with increasing strength and duration of the current. This has to spread itself over the whole course of the affected nerve as much as possible. I will leave it an open question whether it is advisable to apply the anode peripherally from the kathode —say, on the muscles—in order to get the so called 'refreshing' action; it is probably comparatively immaterial.

(*c*) A further task is the *removal of the secondary nutritive disturbances*, grosser or more minute, which may be present in the motor tract, and which interfere with the normal function, in this case chiefly with the conduction.

There are two things here with which we may have to do: in the first place, with finer molecular disturbances, produced in the nerves by poisons, for example, or resulting from prolonged disease, perhaps also from the loss of certain central trophic influences, and constituting an obstruction to the passage of voluntary stimulation, as in cerebral hemiplegia, according to Brenner's showing. One or more moderate excitations, the repeated traversing of the motor tract by electrical stimuli, is often sufficient to restore the conduction, and stimulation of the trophic tracts and centres may perhaps play a certain part in the result. However it may be, sudden and great strides towards improvement are often seen under favourable circumstances, and a part of what we have described in cerebral diseases as 'the reduction of the functional disturbances to the dimensions corresponding to the anatomical changes' certainly belongs to this category (p. 333). (May not reflex action also play a greater part in it?)

But we may have to do, in the second place, with the well-known *degenerative atrophy* of the nerves, which results from the entire cutting off of central trophic influences, and which may be recognised by the presence of RD. Experience certainly teaches that a complete arrest of this degenerative atrophy is impossible, however early and diligent the electrisation may be; for where the trophic centres are completely cut off it comes on inevitably, and any improvement can only be expected if the conduction begins to be restored. But, although it has not been directly proved, it is still very probable that, by means of regular faradic and galvanic stimulation, extensive atrophy of muscles at least may be prevented, and the subsequent regeneration of the nerves and muscular fibres accelerated. We must aim at katalytic and trophic actions, increase of the blood supply, and the earliest possible return of the excitability, in order to promote the regeneration and to check the degeneration. The faradic current will have very little effect here, even if it will not be altogether useless. In any case the galvanic current is to be preferred—the stabile action of both poles on the diseased section of nerve, then the energetic labile action of the same, and afterwards also the treatment of the muscles themselves, to be described presently.

(*d*) Finally, there remains still in many cases the problem of *restoring the normal irritability, contractility, and power, perhaps also the normal size of the paralysed muscles*, and this is very essential to the cure of the paralysis. Here also, as in the nerves, we have partly molecular and more minute nutritive disturbances, partly simple atrophy, wasting from disuse, external pressure, &c., partly true degenerative atrophy, as I have described it to you in its own place (Lect. X., p. 190).

This brings me at once to speak of the treatment of muscular atrophy as such, for it is essentially the same whether the atrophy proceeds from a nerve lesion and is associated with paralysis, or has resulted idiopathically, from primary muscular disease or disuse, from long-continued surgical bandaging, joint affections (reflex?), or in any other way. The surest means of increasing the nutrition and contractility of the muscles is the inducing of muscular contraction itself, as muscles which are frequently thrown into contraction hypertrophy and become stronger. But more careful consideration, combined with physiological experience, shows that we have to do here with a very complex procedure. At the same time as the motor stimulation a stimulation of the vasodilators certainly takes place, the consequence of which is an increased amount of blood and a rise in the temperature of the muscles. A simultaneous stimulation of the trophic tracts, causing acceleration of the processes of tissue metamorphosis, and thereby an increased growth of the muscular fibres (which cannot be accounted for by the increased determination of blood alone), seems to me to be probable.

For the accomplishment of our purpose—the removal of the atrophy and degeneration of the muscles—we have, therefore, to produce an increase of the irritability of the contractile substance, so that it may be more easily stimulated; frequently repeated excitation of it, to induce muscular contraction; vasomotor influences, increasing the determination of blood to the muscles; and, finally, trophic action from the nerve upon them, either directly or indirectly.

These are, as you see, gentlemen, a number of problems which seem as if they were created for electrotherapeutics, especially for the *galvanic current.* By its means we may first act stabile with the kathode, alternating with the anode (on account of the remaining positive modification) on the muscle itself, whereby we attain increase of the irritability and probably also katalytic trophic actions; then we may make an energetic stabile action with both poles (alternately or simultaneously) on the corresponding motor nerves, on account of the vasomotor effect; and, finally, labile galvanisation of the motor nerves and the muscles in order to set up muscular contractions, and indirectly to stimulate the trophic influences. For this you will generally employ the kathode; but if RD is present, the labile stimulation of the muscles themselves may very well be undertaken with the anode. If you need still stronger irritation, KC and changes of polarity, or galvano-faradisation, may be resorted to. If the irritability of the muscles is very much lowered you must often begin the course of treatment with frequently repeated reversals, until it is to some extent improved. You act in exactly the same manner with the *faradic current*: you stimulate the muscles, or, still better, their motor nerves, by means of moist electrodes, according to the rules of local faradisation; that is the simplest and best procedure, especially in all cases where the faradic irritability has not been lost.

Of course it is only very gradually, by means of increased nutrition, that an improvement in the volume of the muscle, an increase in the transverse section of the muscular fibres, and thereby in the power and activity of the muscle, can be attained. This may occur with greater or less rapidity. In favourable cases it is often surprisingly rapid, in unfavourable very slow, and it may even fail altogether if the possibility of central trophic influences is permanently annulled. But that such a result can take place in a few minutes no one will believe; the 'distension' of the muscles under the influence of a galvanic current of a few minutes' duration, so often described by R. Remak, can only be explained by vasomotor influences, dilatation of the vessels, increased blood supply and absorption of fluid, and you cannot fancy that the muscular fibres themselves take any noteworthy part in it.

I must mention yet another method of treatment of muscular atrophy, of which some observers have reported very favourably—that is, the *employment of weak continuous currents* (from 1 to 4 cells). Le Fort and Valtat have employed it (this method) in the muscular atrophy which is so common after articular inflammation, and have repeatedly seen very good results from it. It appears to be particularly indicated in the peculiar forms of muscular atrophy without degenerative processes and without RD, which may be referred to reflex influences (especially from the joints), disuse, long-continued surgical bandaging, and the like. Charcot has recently made this atrophy the subject of an exhaustive consideration. He has found that the muscles present simple diminution of faradic and galvanic irritability (as was pointed out long ago by myself and by Rumpf), but that they still react readily to static electricity, to which he ascribes very good therapeutical effects. I have already (p. 285) described the methods of Le Fort and Valtat in the treatment of this atrophy, and I would refer you to that.

A retrospective glance over the tasks set us in paralysis and atrophy, and the methods of fulfilling them, shows that we have to do principally with the stimulating action of electric currents, that the vasomotor and trophic—that is, the katalytic—

actions may also come into operation (the latter playing the principal part in the fulfilment of causal indications), but that the modifying, exciting actions are only of subordinate importance.

As essentially the same methods of application are required for all the indications before us, the electrotherapeutics of paralysis is simplified more than you would, perhaps, have expected after the long explanations which we have been giving until now. Apart from the procedures demanded by the causal indication (treatment of the brain, the sympathetic, the spinal cord, or the peripheral nerve lesion) the direct antiparalytic effects of the current may be induced, as a rule, by simple faradisation of the nerve trunk concerned at certain points, or by chiefly labile, afterwards also stabile galvanisation of it, which may, of course, be modified and graduated in the most manifold ways, according to the situation, the nature, and the extent of the lesion. To this may then be added peripheral cutaneous excitation or the irritation of sensory nerve trunks, which is in many cases desirable, if it has not already been included in the rest of the procedure.

After these applications the results will be seen to come on more or less rapidly and completely; in particularly fortunate cases they may be rapid, even after one single sitting or after very few, if the anatomical changes are of such a nature that a rapid restoration of conduction is possible, or if such has been prepared for in the course of the affection by the curative power of nature. In such cases we see movements which have been impossible for weeks and months suddenly return, as, for example, in paralysis of the vocal cords, hysterical paralysis, certain cerebral paralyses, slight rheumatic paralysis after it has existed for some time, even in paralysis with RD, if electrisation is begun at the proper time, when regeneration has already advanced a certain length, &c.; but such cases must always be looked upon as exceptions, and most paralyses require a more or less prolonged treatment, the end being attained only by patience and perseverance. In any case, you must not let failure at the beginning deter you from the continuation or the repeated resumption of the treatment so long as there is any well-grounded evidence of improvement, for every now and then we see improvement after a surprisingly long duration of the disease. All paralyses with complete RD require a very long course of treatment, and in such the improvement depends entirely on the removal of the cause of the paralysis, which often takes a very long time. In paralysis with an absolutely incurable cause you must not, of course, prolong the electric treatment unduly.

It appears to me superfluous to cite a number of therapeutical facts in proof of what has just been said; for if anything is certain and undisputed it is the therapeutical effects of electricity in paralysis, of which we have more than sufficient experience. I have already quoted a number of examples in previous lectures (vide Obs. 5 to 12, 15 to 17, 18, 20, 21, 22, 32 to 34, 37 to 41), to which I would refer you, and I shall give a few more under the special forms of paralysis.

I need not say much in this place either about the *electrodiagnosis of paralysis*. Electrodiagnosis as a whole has been principally studied and established in connection with paralysis, and is, without doubt, of the greatest importance in relation to it. Referring you to the General Part (Lectures VIII. to XI.) for what I have said there on the subject, I shall here give only a short résumé, which will be further filled up in treating of separate forms of paralysis.

The first thing that we expect from electrical examination is information as to the exact *situation of the paralysis*. In this respect I must beg you to moderate your expectations very much, for electric testing very seldom gives us certain information as to the exact seat of the lesion. That is sometimes to be had in peripheral paralysis, in which the central portion of the nerve is accessible to electrical stimulation; if the central portion is non-excitable while a more peripheral part still is, then the lesion *must* lie between the two stimulated points (but even this is valuable only in cases where there is no complete RD). Further, we may conclude with certainty, from the presence of more severe disturbances of the electrical irritability (great lowering, RD), that no essentially cerebral paralysis is present, for such a condition occurs only in spinal (including bulbar) and peripheral paralysis. If you find, for example, such serious changes in a cerebral nerve (facial, spinal accessory, &c.) you know that it must be injured in its peripheral tract, or at least in its bulbar nuclear region. On the other hand, a distinction between peripheral and spinal paralysis is not possible on the ground of electrical examination alone; but if you have an undoubtedly spinal cause for a paralysis you may very well decide, with a fair amount of certainty, from the presence or absence of RD, on the implication or immunity of certain sections of the anterior grey columns.

The information which electrical examination gives us as to the *presence or absence of severe degenerative processes in the paralysed nerves and muscles* is much more important, and here especially the different forms and stages of RD are of the greatest possible significance, because they give us a fairly accurate impression of the histological condition of the nerves and muscles, and thereby allow us to form a correct conclusion as to the *severity of the paralysing lesion* and the degree in which conduction is affected. By this means also very important prognostic data are in many cases furnished, and in any case very special attention must be paid to these circumstances in all forms of paralysis. For all details I refer you to the General Part.

Finally, still slighter changes—simple increase and simple diminution of the electrical irritability—occur, from which certain conclusions as to the degree of irritability generally, the finer molecular and nutritive disturbances, &c., may be drawn, which are certainly not of much diagnostic value, but which now and then justify important conclusions. Thus a slight increase in the electrical irritability, which shows itself in many cases of paralysis within a few days, in others after a longer time, admits of the certain conclusion that slight irritative conditions exist in some part of the motor tracts (as in hemiplegia with contraction, neuritic paralysis, at the commencement of certain rheumatic paralyses, &c.) A diminution of the electrical irritability indicates, in many cases, finer nutritive disturbances (from disuse, or the lack of certain trophic influences in many spinal and cerebral diseases, which do *not* lead to RD); in other cases, again, the loss and atrophy of the greater part of the nervous and muscular fibres, as we see in bulbar paralysis and in some of the muscles in progressive muscular atrophy; or, finally, grosser changes in the muscles themselves, which cause atrophy or some other disturbance of the muscles, and thereby lead to a diminution of the irritability (as, for example, in muscular atrophy in the neighbourhood of diseased joints, in primary muscular diseases, in lipoma and pseudohypertrophy of the muscles, in true muscular hypertrophy, &c.) From all that we know, the presence of RD indicates that the paralysis or atrophy in question is of neurotic orgin, and must be caused by a lesion of the peripheral or central trophic nervous apparatus; in all cases, therefore, where you find marked atrophy with corresponding paralysis and without any RD you may exclude with certainty a neurotic origin, and think of a primary muscular disease. At all events all *severe* lesions of the grey anterior columns, or of the peripheral tracts, may certainly be excluded, even if we cannot entirely exclude the possibility of some other kind of central disturbance of nutrition (cf. pp.173–176); but there are no very decided proofs of this. The facts already deduced from spinal pathology are not sufficient to determine this, and the views lately advanced by Charcot—that the atrophy following articular inflammation is also of neurotic, spinal origin—is at present only a hypothesis, albeit a very plausible one.

Before proceeding to the special consideration of the individual forms of paralysis I shall preface it by a few short practical and general remarks.

In the treatment of *cerebral paralysis* the central treatment is, of course, the principal thing; for its commencement and method I would refer you to Lectures XVI. and XVII. In the peripheral treatment of the paralysis, an exception must be made to the above-mentioned rule of applying the anode to the seat of lesion, on account of the danger of applying too strong a current to the brain; in such cases I generally place the anode on the nape of the neck, whilst I treat the arm and leg peripherally. Sometimes I have passed stabile, but very weak, currents from the side of the cerebral lesion to the opposite brachial plexus, as an introduction to the peripheral treatment. Caution in the selection of the strength of the current is specially enjoined in cerebral paralysis, more particularly if reflex irritation (farado-cutaneous brushing) is resorted to.

In *spinal paralysis* also the central treatment is the principal thing; and the peripheral treatment may sometimes be dispensed with, especially if the nutrition of the nerves and muscles is normal and their electrical irritability intact (vide Lectures XIX. and XX.) Here we may adhere to the rule to apply the anode over the seat of lesion in peripheral treatment.

In *peripheral paralysis* the seat of lesion deserves the first consideration; afterwards an accurate balancing of the special relations is required, in order to settle the situation and the manner of further applications. The difference of the effect on the motor and sensory tracts, the consideration of the direct or reflex stimulation, ought not to be neglected; and, in particular, the reflex stimulation ought, perhaps, to be cultivated more, and more consciously, than has hitherto been done.

In respect of the *technique* of the operation there is but little to say. The strength of the current must be suitable to the individual case, and must generally be sufficient to induce contraction (where excitability is destroyed the healthy side may be used as a test); and the electrodes must be selected according to general rules—for causal treatment somewhat large, but for the peripheral relatively small. More exact localisation is determined by the special relations of the individual case.

The sittings must not be too long, or over-stimulation and exhaustion will be induced; and the duration of the entire course of treatment must be according to circumstances, determined by the general rules (Lect. XV.) You must not fail in perseverance in the electrotherapeutics of paralysis.

LECTURE XXIII.

Electrotherapeutics of the Separate Forms of Paralysis—1, Paralysis of the Ocular Muscles—Pathogenesis—Cases—Methods of Treatment—Results—2, Paralysis of the Muscles of Mastication—3, Paralysis of the Facial Nerve—Rheumatic Form; its Situation and Nature—Conditions of the Electrical Irritability — Prognosis — Cases — Methods of Treatment — Results—Other Forms of Facial Paralysis—4, Paralysis of the Spinal Accessory Nerve—5, Paralysis of the Hypoglossal Nerve.

THE *treatment of the separate paralyses* is to be carried out according to the principles set forth in the previous lecture; it is very different in the different cases, according to the situation of the lesion, with regard to the indications present, and the most suitable methods of application. I must now describe this somewhat in detail.

1. PARALYSIS OF THE OCULAR MUSCLES.

This occurs very often, either idiopathically or as an accompanying and diagnostic symptom of a great number of important diseases of the brain, and also of the cord. It is of great importance for the diagnosis and discernment of many of these diseases, and constitutes a very grateful object for electrotherapeutics.

The basis of electrical treatment must, of course, be a diagnosis, as exact as possible, of the form and extent of the paralysis, and especially of the localisation of the lesion. The recognition of the paralysis of the separate muscles of the eye has developed to a high degree of perfection. There is isolated paralysis of individual muscles or of each separate ocular nerve, partial paralysis of the oculo-motorius, then combined paralysis of all or of two ocular nerves, one-sided and symmetrical muscular paralysis, and finally symmetrical paralysis of associated muscles having the same action (e.g. both superior recti, internal rectus of one side and external rectus of the other, both internal recti, &c.), and we must also distinguish between complete paralysis and mere paresis, the so called insufficiency of the ocular muscles.

The exact seat of the lesion may be deduced in many cases, but not always, from all these conditions, from ætiological circumstances, and from well-known facts of clinical experience; it may be in the orbit (the three ocular nerves, the optic nerve, the first branch of the trigeminus), or in the middle cranial fossa (three ocular nerves and the whole of the trigeminus), or in the posterior cranial fossa (trochlear nerve, abducens, facial, auditory, &c.), or it may be situated in the bulbar nuclear region, medulla, pons, peduncle (nuclear oculo-muscular paralysis, implication of functionally associated muscles, immunity of the accommodation and pupillary reflexes, implication of other bulbar nerves, alternating paralysis, &c.) There is not much known as yet about the more centrally situated lesions as causes of oculo-muscular paralysis. Some observations favour the idea that cortical lesions may give rise to muscular paralysis, e.g. isolated ptosis and the like, on the opposite side, but a more exact localisation cannot be made; the other symptoms must be considered in determining it.

Further, the diagnosis whether such paralysis is to be considered as the precursor or the accompaniment of other diseases, especially tabes, multiple sclerosis, and the like, is of more particular importance; and a thorough examination of the disease with this end in view often gives surprising disclosures. It is, of course, also desirable to obtain information as to the nature of the lesion, for in certain disturbances (tumours, syphilis, &c.) nothing at all can be expected from the electrical current, or only in combination with other treatment.

There is no *electrodiagnosis* of oculo-muscular paralysis, as the ocular muscles cannot be stimulated by electricity; so we must resign the advantage which electrical examination grants to the diagnosis of many other forms. I have often tried to obtain results from it, but the near neighbourhood of the brain and of the retina lays limits upon us in the choice of the strength of the current, such as will always render an exact examination impossible.

I will now cite shortly a few cases as examples for the therapeutical results.

51. *Personal Observation. Rheumatic Paralysis of the Abducens.*—An engine-driver, aged 34, had suffered from diplopia for 10 days, apparently from a chill. Right-sided abducens paralysis is present;

the eye cannot be moved outwards beyond the middle line. Galvanic treatment: 8 cells stabile, transversely through the temples, galvanisation of the sympathetic, the kathode labile along the region of the rectus externus, the anode being on the left side of the neck. Immediately afterwards the eye could be moved farther outwards. After the fourth sitting the double images closer together, the eye able to be carried almost into the external angle. After 10 daily sittings, cure.

52. *Personal Observation. Right-sided Oculo-motor Paralysis.*—A man, aged 70. Diplopia now and again for two months. On March 20, 1867, sudden and complete ptosis of the right eye, since when the eye has remained closed; fleeting pains in the depths of the orbit and in the right half of the forehead. On April 1 complete paralysis of all the muscles supplied by the right oculo-motor nerve. Abducens and trochlear nerve unaffected. Otherwise perfectly healthy, with the exception of senile palsy in the right arm. Galvanic treatment: 12 cells with the kathode labile over the eye, the anode being behind the left ear. On April 12 distinct improvement; the eyelid can be raised half-way. Gradual return of motility to the other muscles, but complete cure not till May 24, after 28 applications.

53. *Personal Observation. Right-sided Trochlear Paralysis and Insufficiency of the Internal Rectus.*—A man, aged 52, suffering for 14 days, probably in consequence of an injury, from symptoms of paresis of the right obliquus superior with insufficiency of the internal rectus. Treatment began on October 19, in the usual way. Immediate result very striking, the diplopia disappearing at once, to return, however, until the following day. On November 1 the insufficiency of the internal rectus completely removed. Treatment discontinued from November 3 to 8. On November 8 diplopia again a little more marked, but disappeared at once after the treatment. On November 15 patient discharged cured.

54. *Personal Observation. Double-sided Paresis of the External and Internal Recti (Nuclear Oculo-muscular Paralysis ?).*—A boy, aged 12, formerly always healthy. Diplopia for 4 weeks, after 2 days of severe pain in the head; his rigid look very remarkable. Examination shows vision normal, accommodation not impaired. Both external as well as both internal recti appear extremely paretic (the double image homonymous on distant vision in the external half of the field, crossed on near vision.) The other ocular muscles appear intact, as are all the other cerebral nerves; no more headache, no vomiting, a little dizziness in walking, extremities unaffected.

Galvanic treatment: 8 cells transversely through the temples and the mastoid processes, then the kathode labile over the eyelids.

After 8 days—adduction now almost normal—no more double images on near vision; abduction, on the other hand, still much embarrassed. After 11 days, improvement in the external recti, the double images nearer each other. Severe epistaxis came on, after which the diplopia disappeared, and the external rotatory movements of the eyes became much greater; cure after another week.

The *methods of treatment* for oculo-muscular paralysis may be deduced very simply from general rules. The conditions which are present in regard to the situation and the etiology of the paralysis will lead us in most cases to have recourse to the galvanic current first of all. At the same time we must not deny all effect to the faradic current; you cannot expect, however, that it will develope any considerable katalytic actions, but only that it will have a slight influence on the muscles and their motor nerves, perhaps all the more because it influences them reflexly from the skin.

The first thing to be undertaken is the *galvanic treatment of the seat of lesion*, and in such a way that, after it has been made out, the current shall be directed transversely through the anterior or posterior temporal region or through the mastoid processes, the anode being on the affected side; in most cases, however, it is advisable to let the kathode act there afterwards. A very practical method of application, by which means the whole tract of the oculo-motor nerves, as far as their nuclear region, is brought into the domain of the densest part of the current, is to place one electrode on the closed lids of the affected eye and the other on the opposite side of the neck and of the occiput. For this purpose you use 'medium' electrodes, a weak current (10–20–25° N. defl. with 150 GR, 1 to 5 ma.), and stabile action for 30 seconds to one minute in each situation. If a cortical affection is suspected the suitable application for it must be made. You may also *galvanise the cervical sympathetic*, as Benedikt recommended; for the various connections which exist between the sympathetic and the ocular nerves, by means of the carotid and the cavernous plexus, make the possibility of a beneficial influence apparent even apart from the direct katalysis of the lesion itself. You will employ the usual methods for this purpose. I will not enter into the question whether the conjecture put forward by Rieger and v. Forster—that we have to do, in tabetic and other similar forms of oculo-muscular paralysis, frequently with local, vasomotor disturbances, which proceed from primary centres of disease in the spinal cord—is sufficient to institute the treatment of the cord, especially of its cervical portion, in such cases.

But the chief thing is the *direct excitation* of the paralysed muscles by means of the kathode. You will accomplish this best by fixing the anode in the nape of the neck (a little towards the opposite side) and passing the kathode backwards and forwards over the closed lids, near to the insertions of the muscles which are chiefly to be influenced, and also letting the kathode act stabile for some time on the same spots; thus, for the internal rectus on the inner side, for the superior oblique inwards and upwards, for the superior rectus and the levator palpebræ superioris chiefly upwards, &c. For the abducens the temple may be treated labile in the direction of its situation. The strength of the current should be sufficient to cause distinct burning on the lids, and lively contraction of the frontal muscles when the temple is treated; the time for each muscle should be about half a minute. Guard against too considerable irritation. It is a good thing to test the immediate effect, and to stop when it ceases to progress. The 'small' sponge electrode will serve the best, but with a little dexterity you may also employ the 'medium' size. It is also advantageous to use the index finger, covered with a damp cloth, as an electrode, and so to allow the current to pass through your own body, as a check upon its strength (Buzzard); that, however, is more to be recommended for the faradic current. The same proceeding may be practised if paralysis of accommodation or any other affection of the pupil be present; and the irritation must then be made with the kathode, in a circular direction to the bulb itself.

The same method of application, as I have just indicated, will be chosen for the *faradic current*; the current tolerably strong, so that the orbicularis palpebrarum may contract well; the electrode to be applied in the region of the muscle to be stimulated. We may get nearer to the muscles here by using as an electrode a moistened hair pencil, as Gozzini recommended, or a small knobbed electrode (M. Rosenthal), introducing it into the conjunctival sac and bringing it as near as possible to the insertion of the muscle; but this is very disagreeable to the patient, and may at the same time not be sufficient to induce contractions of the muscles. You may also treat mydriasis, &c., in this way with two fine hair-pencil electrodes, placed opposite each other on the margin of the cornea; but this is best done under an anæsthetic.

In this way *direct stimulation* of the paralysed muscles and of the motor tracts may be carried out; but that this can only be weak and imperfect is evident from the unfavourable nature of the existing anatomical and physical relations, and depends also upon the impossibility of making the ocular muscles contract by means of electricity. Hence we may suppose that the cures reported to have been effected by this treatment have depended upon *reflex stimulation*, and Benedikt has, indeed, asserted that the irritation of the skin, i.e. of the trigeminus, was the main thing. The *possibility* of such reflex influence is certainly not to be denied, but the facts to prove its existence are wanting. So far as I know, nothing is known in physiology of an intimate reflex relation between the skin of the face and the ocular muscles. I have myself sought in vain to prove it by strong faradic irritation of the skin round the eyes, and in all my many attempts to induce dilatation of the pupil by means of irritation of the skin I have never been able to discover any movement of the external ocular muscles. I cannot, therefore, believe thoroughly in those reflexes, and must resign, however unwillingly, this convenient way of combating ocular paralysis. For the rest I need hardly say that the methods just described serve also for the purpose of reflex stimulation from the skin.

The *results* of the electric treatment are very favourable in many of those cases which are at all suitable for it. The instantaneous improvement which comes on immediately after treatment is often especially striking; the movements of the eyeball are more extended, and the double images come nearer together. If this continues, and is repeated day after day, recovery is rapid; but frequently it takes much longer, the improvement disappears again, and recovery is put off for a long time. A longer course may be calculated upon if the power of movement increases more rapidly than the approximation of the double images. But there are plenty of cases in which galvanic treatment, like all others, remains ineffectual, and the paralysis is not cured.

There are hardly any general data for the results which may be expected from the treatment. Rheumatic paralysis is usually cured quickly and easily, and the traumatic forms are not unfavourable; paralysis in the initial stages of tabes is generally very favourable for therapeutics, but still there are exceptions, and the same may be said of diphtheritic oculomuscular paralysis; I have never succeeded with spinal myosis and reflex Argyll-Robertson pupil in tabes; mydriasis and paralysis of accommodation are generally very obstinate also, but all depends upon the nature of the cause.

2. Paralyses of the Muscles of Mastication

(the motor portions of the trigeminus) are among the greatest rarities. They are most frequently caused by intracranial, and especially by basal diseases, and they may also occur in certain bulbar affections (Erb); but there is seldom any sign of their participation in more central cerebral diseases (pons, central ganglia, cortex, &c.) Occasionally atrophy, loss of faradic irritability, and RD are associated with the paralysis.

The electric treatment is carried out on the same plan as in ocular paralysis; first *rational* (the galvanic current transversely through the anterior or posterior auricular region, or diagonally from the front of the ear to the opposite side of the neck, &c.), and then the *direct excitation* of the masticatory muscles by means of the faradic current, or with the kathode labile, or KC, &c., on the given points (fig. 29, p. 292), for which only the external muscles (masseter, temporal) are accessible. A reflex action, induced by irritating the sensory twigs of the trigeminus, may also be mentioned. The results, of course, vary with the cause of the disease.

3. Paralyses of the Facial Nerve.

These are the most frequent and also the most satisfactory subjects of electrotherapeutics. They cause so much disfigurement and other inconvenience that patients seek help without delay; they are, further, so common, and have been made the object of special scientific investigation in so many different directions, that there is hardly any other paralysis on which we are so well informed as on this.

This is especially true of *rheumatic facial paralysis*, by far the most frequent and practically the most important form; its symptomatology, its electrical conditions, its therapeutics have become typical for all other forms of facial paralysis; we shall therefore consider it first and exclusively. The electrotherapeutics of the other forms can then be disposed of in a few words.

Nothing is easier to recognise than a rheumatic facial paralysis; the typical deformity of the face, its want of symmetry in movement, both mimicking and voluntary, the fact of the eye being open, &c., in conjunction with the previous exposure to cold and the rapid onset of the affection, in the absence of any other disturbance of the nervous system, make it easy.

But it is more difficult to answer the question where the usual *seat* of rheumatic facial paralysis really is to be found, and what its *nature* is; and it is the verdict on these points that must determine the position and the manner of the application of the current in the first place. Now, the whole set of symptoms leaves us without a doubt that we have to do with a lesion of the nerve trunk itself, and in its peripheral part; a central localisation of rheumatic facial paralysis is absolutely excluded. In particular the seat of the disease may certainly be found most frequently in that part of the nerve trunk which lies between the opening of the Fallopian canal and the division of the nerve into the separate branches of the plexus anserinus; from here the disease may extend farther up the Fallopian canal, for a longer or shorter distance, seldom as far as the geniculate ganglion, hardly ever to the base of the skull. How far this is the case may be ascertained in the individual observations, from the implication in the paralysis of the posterior auricular, the chorda tympani, the stapedius muscle, the large superior petrosal nerve, &c. Compare the different handbooks of nervous pathology on this point. But in the great majority of cases the affection seems to begin in the above-mentioned spot in the auriculo-mastoid fossa, and to extend itself from there more or less towards the centre, according to circumstances.

The essential *nature* of the affection, however, is not yet quite clear to us, in spite of the frequent occurrence of rheumatic facial paralysis; post-mortem investigations are wanting, but from all that we do know there is hardly any doubt that a slight rheumatic neuritis is present. The exposed position of the nerve at the spot mentioned, the tenderness of the skin in that region, the absence of protection from the hair of the head or of the beard, and the tendency to sweating in its neighbourhood make it plain why the effects of cold, operating on one side of the face, should lead so easily to inflammation just at that point. On the other hand the narrowness of the Fallopian canal causes a small amount of inflammatory swelling of the nerve to lead to a very considerable compression of it, and thereby to a serious limitation of its conducting property; whereas if the process is limited to the short portion outside the canal the injury to the nerve is much slighter and more temporary.

It is perfectly in accordance with this that rheumatic facial paralysis has a very different gravity and duration in different cases. Cases arising apparently in the same manner, with exactly the same symptoms at the beginning, have a very different course; in some recovery takes place in two or three weeks, but in others it may be many months, even a year and more, before the last traces of the affection have vanished.

In *electrical examination* we possess an excellent means of recognising early and with perfect certainty the sources of these different conditions, which are to be found exclusively in the severity of the lesion and in the consequent changes—degenerative atrophy—of the nerves and muscles; and we are thus enabled early to give an accurate prognosis in the several forms of rheumatic facial paralysis. In scarcely any other form of paralysis have the conditions of electrical irritability been so frequently and thoroughly investigated as in this, and the phenomena of RD have been thoroughly studied only in such cases.

In the first group of cases there is *no alteration at all in the electrical irritability*, or, at the most, a very slight increase for one or two days at the beginning of the paralysis. Subsequently the faradic and galvanic irritability in the nerves, as well as in the muscles, remains qualitatively and quantitatively entirely normal. In all these cases *the prognosis is very favourable*; they recover in the course of two or three weeks, very seldom lasting longer (*slight* form of rheumatic facial paralysis).

In the second group you find also no alteration at first, except perhaps a slight increase of irritability, but towards the end of the first week you will manage to recognise a very slight diminution of the faradic irritability in the nerves and muscles, more distinct in the diminution of the maximal than in the subsequent appearance of the minimal contraction; this does not increase further, and does not reach any great amount, but in the course of the second, or perhaps not till the third week the characteristic changes of RD make their appearance in the muscles, and sometimes attain a very complete development. *Partial RD*, then, is found here. It is often very interesting to notice that the muscles, when stimulated through the nerve, react in a normal manner (with short contractions and predominance of the KCC), but with direct stimulation abnormally (tardy contractions, preponderance of ACC). This form also warrants a *relatively good prognosis*: the disease is cured in four or six weeks, seldom requiring eight or ten; the motility is often almost completely restored before the galvanic irritative changes in the muscles have disappeared; and the cure is a complete one, without subsequent contraction or spontaneous spasmodic twitching in the facial muscles. (*Intermediate* form of facial paralysis.)

Finally, a number of cases belong to the third group; these are those in which all the symptoms of *complete RD* make their appearance at once and in a most complete manner, the irritability of the nerve twigs diminishes very rapidly and is extinguished, whilst the muscles suffer the characteristic changes in the faradic, galvanic, and mechanical excitability. The *prognosis* here is *decidedly unfavourable*, for these cases always require a very long time to recover. The first traces of returning motility begin to show themselves after two or three months, and several months more may have passed before the cure is nearly complete, that generally occurring only after a certain stiffness of the paralysed side of the face, contractions, muscular twitchings, &c., have existed for a long time. This may take from six to ten or fifteen months, and the eye of an expert can often discern permanent traces of the former paralysis. (*Severe* form of facial paralysis.)

It is scarcely necessary to point out that every possible gradation between the slight and the severe forms may exist—that the intermediate form joins closely on to the slight on one side and may pass imperceptibly into the severe on the other.

We find ourselves, then, in the satisfactory position, at the end of the first week (in severe cases even earlier), of being able to give an absolutely certain prognosis of the duration of the affection, by means of the electrical investigation, and that is often of great service in such a disfiguring ailment. If we find at the end of the first week that there is not a trace of diminution of the irritability of the nerve (after *very careful* investigation), then the affection will last two or three weeks; if there is a *slight* diminution, we must reckon upon four or eight weeks; but if at this stage there is a *great* diminution of irritability it will last at least for several months, from four to twelve. There are, of course, sometimes exceptions and transitions. Neither the age of the patient nor the earlier or later commencement of the electrical treatment has any influence upon the varying severity of the disease.

There is no doubt that this very diverse course of one and the same disease can only be caused by the varying severity of the lesion—by the greater or less degree of compression and destruction which the nerve has suffered from the rheumatic affection. But, further, it seems to me quite beyond a doubt, or at least extremely likely, that this varying severity of the lesion is for the most part, if not entirely, the consequence of the localisation of the disease: if it affects the part of the nerve lying in loose tissue entirely outside the Fallopian canal much compression is impossible, the lesion remains slight and soon passes over; but if the affection (neuritic swelling, &c.) extends as far as the funnel-shaped entrance of the canal, and even inside it, the pressure on the nerve fibres becomes more intense with the increasing narrowness of the space, and the hindrance to the conduction more complete; not only the motor but also the trophic conduction is completely interrupted, and we have the various degrees of RD and of degeneration, with, of course, a much longer duration of the affection. The symptoms of these cases correspond entirely to this (with very rare exceptions); the implication of the higher branches (chorda tympani, stapedius, &c.) is only found in the severe forms. Of course this does not exclude the possibility of the greater or less intensity of the disease itself having some influence in determining its duration and severity.

Other and rare anomalies of electric irritability, observed now and then in rheumatic facial paralysis—simple increase and simple diminution of the faradic and galvanic excitability—are of no diagnostic importance whatever.

Let us now consider a few typical examples of this daily-recurring malady.

55. *Personal Observation. Rheumatic Facial Paralysis. Slight Form.*—A woman, aged 24, suffering for 6 days from rheumatic paralysis of the right facial nerve. Uvula and soft palate symmetrical; no disorders of taste or hearing. Electric irritability of the nerve twigs and of the muscles entirely normal. Galvanic treatment. On the 10th day of the disease the first trace of returning motility; recovery in 18 days. The electric irritability presented no anomalies at any time.

56. *Personal Observation. Rheumatic Facial Paralysis. Slight Form.*—An office porter, aged 41. Paralysis of the right side of the face 8 days previously, from chill; complete paralysis of all the facial twigs, reflexes suspended, no disorder of taste, soft palate unaffected. Faradic and galvanic irritability completely normal. Galvanic treatment. On the 11th day of the disease distinct improvement. On the 17th day cure almost complete. On the 23rd day (after 5 sittings) discharged cured. The electric irritability never showed any alteration.

57. *Personal Observation. Rheumatic Facial Paralysis. Intermediate Form.*—A forester, aged 41. Left-sided facial paralysis in consequence of a chill. Condition on the 18th day: Complete paralysis of the left side of the face. Uvula and soft palate normal; no disturbance of sense of taste. Partial RD (with the faradic current the nerve twigs

respond when the secondary coil is drawn out 8 or 10 millimetres less than is necessary on the right side; with the galvanic current there is a slight diminution in the nerve twigs, and in the muscles the characteristic increase and qualitative alteration, ACC > KCC, increase of mechanical irritability). Galvanic treatment. 22rd day, decided improvement present. 56th day, recovery nearly complete; galvanic irritability of the muscles still increased, that of the nerves nearly returned to normal. 65th day, discharged cured.

58. *Personal Observation. Rheumatic Facial Paralysis. Intermediate Form. Transition to the Severe Form.*—A student, aged 21. Suffering from left rheumatic facial paralysis for 4 days; paralysis of all the branches of the facial, uvula and soft palate normal, hearing normal, disturbance of taste on the left half of the tongue anteriorly. Electric irritability completely normal. On the 7th day distinct diminution of the faradic irritability of the nerve twigs (from 7 to 16 millimetres of the secondary coil), no trace of RD. On the 13th day faradic irritability still more depressed, especially in the twigs supplying the chin; distinct galvanic RD in the chin muscles, at the same time traces of returning motility in the frontalis. Patient went away. After 2 months motility completely restored in the frontal region, but still defective in the muscles of the upper jaw and of the chin. Taste normal. Electric examination shows partial RD, specially distinct in the above-mentioned muscles. Galvanic treatment resumed; decided improvement in the motility after each sitting. Recovery after 4 weeks, only slight involuntary movements remaining behind.

59. *Personal Observation. Rheumatic Facial Paralysis. Severe Form.*—A woman, aged 62, seen on the second day after the sudden appearance of right-sided rheumatic facial paralysis. Complete paralysis of all the facial twigs; uvula and soft palate normal. Under almost daily observation the development and course of complete RD could be recognised and proved in the most exact manner. At the same time regular galvanic treatment (K labile over the nerves and muscles, A behind the ear) was kept up from the first day. The first trace of motility in the frontalis did not appear till the 66th day, and only increased very slowly. On the 145th day the improvement was pretty far advanced, but a slight contraction of the muscles, especially at the corner of the mouth, had come on. Improvement very slow. Even 13 months after the beginning of the disease it can still be recognised by the impaired motility of the facial muscles, contractions, involuntary movements and twitchings.

60. *Personal Observation. Rheumatic Facial Paralysis. Severe Form.*—A man, aged 36, came under observation 5 days after the sudden onset of a right-sided facial paralysis. Complete paralysis of the facial twigs, implication of the posterior auricular, disturbance of taste, slight hyperacusis, soft palate normal. Complete RD developed itself in the course of the next 14 days. Galvanic treatment (twice a week). The first traces of movement in the frontalis only after 2 months; recovery not nearly complete until 3 months later, and even then some contraction remained behind.

The methods of electric treatment in rheumatic facial paralysis may be inferred from general rules and from our views as to the position and the nature of the affection. The first is the *direct treatment of the lesion itself*; this is best carried out by means of the galvanic current, by passing the current transversely through the auriculo-mastoid fossæ, perhaps also through the petrous portion, in order to remove the existing neuritis; first the stabile action of the anode (especially in recent cases), then a shorter or longer action of the kathode, of about 1 to 2 minutes; 6 to 10 cells will be sufficient (20° to 30° N defl. = 3 to 6 ma.): there are no further difficulties.

On the other hand the *removal of the hindrance to the conduction* is by no means so simple, because we cannot apply the current with the necessary certainty centrally to the seat of the lesion; we cannot stimulate the facial nerve inside the petrous bone or at the base of the skull, and the attempts to do so from the tympanic cavity (by means of an electrode passed deep into the external ear) are, apart from the uncertainty of their result, so disagreeable and painful that no one will wish to repeat them. And every unprejudiced observation compels us to acknowledge that the peripheral electrisation of the nerves and muscles as generally practised cannot contribute much to the fulfilling of this indication. Fortunately we have at our disposal, in this form of paralysis, an unusually efficient reflex circuit, which very much facilitates the desired central stimulation of the lesion. The trigeminus is perfectly intact; a direct reflex connection exists between it and the facial, kept in constant use and in great sensitiveness by countless physiological processes; every energetic irritation of the facial twigs of the trigeminus must set up a corresponding centrifugal stimulation in the trunk of the facial, and that is what we desire. The statement of Russell Reynolds that 'in rheumatic facial paralysis the best mode of treatment is the use of the faradic brush' does not, therefore, appear to me so purposeless as I thought at first; and although I will certainly not advocate the application of this cruel proceeding to the face, still I believe that peripheral faradisation and galvanisation of the face may be of great service, and that the undoubtedly good result of this treatment, which is presumably only directed to the facial twigs and the muscles, is to be attributed chiefly to the stimulation of the trigeminus.

This procedure falls in with that which we employ for fulfilling the last indication, for *removing the finer and grosser nutritive disturbances* in the paralysed nerves and muscles, and thereby restoring the conduction in them. At all events it is of decided advantage in the slight and middle forms; my own investigations as well as subsequent experiences prove that it does not arrest the course of the degenerative atrophy in the severe forms, and probably does not contribute much to the shortening of the whole illness; still it may serve to hasten restitution and to restore the muscles more quickly and completely, and ought, therefore, not to be omitted in such cases. And, as it also serves a directly antiparalytic purpose (reflexly), I must retract my previously given counsel to employ galvanisation or faradisation in severe facial paralysis seldom at the beginning, perhaps once a week, and must regard a peripheral treatment as worthy of being employed quite as often as a rational one; it may be daily.

This peripheral treatment consists in applying—with the *galvanic* current—the 'medium' anode behind the ear of the paralysed side, and treating the nerve twigs and the muscles energetically with the 'small' kathode labile. First pass it over the plexus anserinus and its principal branches; and then take each muscle separately, which will generally cause lively labile contractions. It is of very great service to treat the orbicularis palpebrarum directly, in order to raise its tone and to facilitate the speedy closure of the eye. To do this you must pass the electrode in a circular direction over the lids, closing them with a gentle pressure, but of course taking great care not to let the electrode touch the eyeball. The strength of the current must be sufficient to cause energetic contraction and a distinct burning over the lids; from 6 to 10 cells are generally sufficient, with 20° to 35° N defl. or 3 to 8 ma., for from 1 to 3 minutes.

The *faradic* treatment is exactly the same; in the slight and intermediate forms the separate nerve twigs and muscles must be stimulated, the branches of the trigeminus being of course included; in the severe forms no contraction will ensue, and you must then determine the strength by the feelings of the patient, which must be tolerably acute, and you may pass the small electrodes over the whole face.

The *results* of this treatment differ very much, according to the severity of the cases, but you need never hope to change the severe form into the intermediate or slight form by very early commencement of treatment; the statements to that effect which have been made by some authors are decidedly false. The severity and the average duration of the paralysis are settled things, which you cannot alter much with the treatment. At the same time I believe that in the slight and intermediate forms recovery may be hastened by means of the electric treatment, and that in the severe forms the incurableness of the affection may be prevented, the complete restitution promoted, and the onset of contractions and spasms combated. In the slight forms you may, indeed, see a distinct improvement after each sitting, and also in the intermediate forms, which will soon recover; but in the severe forms you must often go on for weeks and months before any improvement appears, and still longer before cure is effected. The first traces of movement will generally be seen immediately after the galvanisation, or they will regularly become more distinct after it, especially in the orbicularis palpebrarum and the frontalis.

Electricity is generally comparatively useless in *secondary contractions* of the face, especially when they are of very long standing. I have used stabile and labile galvanisation, faradisation of the antagonistic muscles, &c., all in vain, and it is generally necessary to have recourse to other measures, such as mechanical stretching, massage, &c.

The *electrical treatment of other forms of facial paralysis* does not require much further consideration. It may be tried in the greatest variety of ways, and certain modifications must be made in the treatment. Paralysis may occur from inflammation of the parotid or from erysipelas, from traumatic causes (wounds, operations, pressure of the forceps during delivery), from lesions of the petrous portion and of the base of the skull (otitis media, caries, fractures in the petrous portion, hæmorrhage, tumours, aneurisms at the base of the skull), from disease of the facial nucleus in the medulla (in bulbar paralysis, &c.), or of the facial tract in the brain (in apoplexy, cerebral hemiplegia, or, finally, of the motor centre of the facial in the cerebral cortex (in abscesses, tumours, &c.) According to the localisation are the symptoms of the paralysis, their combination with other disturbances and the condition of the electrical irritability. In purely cerebral paralysis the last-named is completely intact; in bulbar paralysis a simple diminution in the facial twigs concerned may be present, and sometimes also partial RD; whilst in all basal, petrous, and otherwise peripheral paralysis the condition of the electric irritability may vary very much; RD, partial or complete, is generally present, sometimes also a simple diminution, very rarely an increase (Brenner), and still more rarely is the irritability quite intact. All these things are of importance only for determining the severity of the lesion.

There are certain modifications necessary in the electrical treatment of all these forms, occasioned by the situation of the lesion, which must be the principal object of the electrical application. In peripheral traumatic lesions, therefore, electricity must be applied to the spot itself; in affections of the petrous portion to the ear and the base of the skull, as in the rheumatic form; in bulbar paralysis, as has already been said (p. 350), transversely through the mastoid processes, or obliquely from the front of the ear to the opposite side of the neck; and in essentially cerebral forms you must choose your methods of application according to the suspected position of the disease in the central ganglia or in the cortex, including galvanisation of the sympathetic. The peripheral treatment, faradic or galvanic, may be the same for all.

4. PARALYSES OF THE SPINAL ACCESSORY NERVE.

These are, on the whole, rare lesions, especially in so far as regards the external branch for the sterno-cleido-mastoid and trapezius muscles. I shall describe later, in their proper sequence, the paralyses of the internal branch, which supplies the larynx, the muscles of deglutition, and part of the velum palati.

Paralysis of the sterno-mastoid and of the trapezius is easy to recognise, but its cause and its exact position cannot always be determined with certainty. It may exist with or without atrophy of the muscles and with or without RD; you have most commonly to deal with a peripheral lesion of the nerve, within or without the spinal canal, and next a bulbar lesion, or it may be a secondary symptom of progressive muscular atrophy, especially of the 'juvenile' form, already described.

The *electrical treatment* is to be carried out according to the rules laid down for the facial nerve, modified according to the seat of lesion and the muscles involved; rational treatment, therefore, through the mastoid processes, galvanisation of the spine, &c., and then the direct peripheral treatment of the points already known. Nothing is known of the reflex relations, but the most natural proceeding would be to make use of the skin over the paralysed muscles.

5. PARALYSIS OF THE HYPOGLOSSAL NERVE.

This is not very rare, but it occurs most frequently only as an accompanying symptom of central affections, such as progressive bulbar paralysis, very regularly in ordinary cerebral hemiplegia, more rarely in cortical lesions. The diagnosis of the seat of lesion is generally easy to make from the whole set of symptoms. Peripheral hypoglossal paralysis certainly may occur (from wounds, operations, the pressure of tumours, cicatrices, &c.), but it has no special practical importance.

In purely cerebral hypoglossal paralysis there is never atrophy of the tongue nor an alteration in the electrical irritability. As soon, however, as the nuclei in the medulla are involved, or the peripheral tract of the hypoglossal injured, atrophy of the tongue is never wanting, and a decrease in the electrical irritability of the tongue and even RD may come on. Bernhardt saw this in one case of division and another of compression of the nerve. Hughes Bennett noticed it in a case of carcinoma involving the nerve; and I have myself observed complete RD in a case of apparently idiopathic right hypoglossal paralysis, and have, like Eisenlohr, seen partial RD in progressive bulbar paralysis.

The *treatment* must be carried out according to general rules, the *direct* treatment corresponding to the cerebral lesion (when the localisation is in the bulb, transversely through the mastoid processes, &c.), and it is very advantageous to press the kathode deeply on the point of irritation of the hypoglossal at the angle of the jaw (vide fig. 29, p. 292), the anode being applied high up in the neck.

For *peripheral* treatment with the galvanic current place the anode also in the neck and the kathode on the spot just mentioned, with labile action or with repeated KC, or else the kathode in the same way directly to the tongue, which may either be stretched forward or laid in the floor of the mouth.

For this purpose it is best to employ an electrode all isolated except a small point of sponge (for the sake of the teeth and lips), and one which is provided with an arrangement for interruption of the current. Movements of deglutition should be induced by external applications, as they are useful for many of the tongue muscles. You will use the same electrode for the faradic current, with which you may easily stimulate the trunk of the nerve at the spot already mentioned, and may also set the tongue itself directly into contraction. The current must be strong enough to induce the muscles to react distinctly.

Nothing is known about reflex irritation of the tongue, apart from the complicated, reflexly induced movements of deglutition.

LECTURE XXIV.

Electrotherapeutics of the several Forms of Paralysis (*continued*)—6, Paralysis in the Neck and Trunk—Pathogenesis—Cases—Methods of Treatment—7, Paralysis of the Upper Extremity—Pathogenesis—Symptomatology—Electrodiagnosis—Examples of Cases—Methods of Electrical Treatment—Results—8, Paralysis of the Lower Extremity—Pathogenesis and Special Forms—Electrodiagnosis—Examples of Cases—Methods of Treatment—Results.

6. Paralysis in the Neck and Trunk.

Under this heading I include the isolated and combined forms of paralysis of all the muscles in the trunk, the thoracic, dorsal, and abdominal muscles, particularly the larger and smaller muscles which move the shoulder-blade, the cervical and dorsal extensors, and finally the most important muscle of inspiration, the diaphragm.

These forms of paralysis are rare on the whole; isolated instances may occur, occasioned by traumatic or inflammatory lesions of their nerves, by compression in vertebral disease, and the like, but we have generally to do with complicated cases, with simultaneous paralysis of different muscles and whole muscular groups, as symptoms of central and generally of spinal diseases. These muscles are paralysed and atrophied very often in progressive muscular atrophy, and it is just they which present the most remarkable combinations of atrophy in the dystrophia musc. progress., which has so often been mentioned (juvenile muscular atrophy, pseudohypertrophy, infantile and hereditary muscular atrophy); in the spinal form, on the other hand, the atrophy comes on in the later stages, and paralysis of the diaphragm may prove fatal.

Some of these paralyses are of very great importance for the working powers of the patients (as paralysis of the serratus, of the lumbar extensors, and of the diaphragm); others, again, only cause insignificant disturbance and deformity, which will be almost entirely made good again, partly by the vicarious function of uninjured muscles. It is impossible to enter more particularly here into the exact symptomatology.

Nor is there much to say about the *electrical conditions* in this paralysis; with few exceptions (serratus, rhomboidei, levator anguli scapulæ, diaphragm) only direct testing of the muscle is possible, the current being applied to the motor points. Occasionally there is a simple diminution of the electrical excitability, in other cases well-marked RD, but sometimes no alteration is to be found; this depends, of course, entirely on the localisation of the paralysing cause and the consequent nutritive disturbances, and requires no further explanation. The diagnostic significance is the same here as in all other cases.

61. *Observation by O. Berger. Paralysis of the Right Serratus Anticus Major, after Enteric Fever.*—A soldier, aged 26. Taken ill with typhoid fever. Towards the end of the fourth week sudden and severe pains in the neighbourhood of the shoulder, radiating towards the arm and along the axillary line; at the same time a sort of 'paralysis' of the right arm, which could not be raised to the perpendicular. The pains disappeared gradually. Six months later isolated and complete paralysis of the right serratus anticus major. All other muscles apparently unaffected; anæsthesia nowhere present, pressure on the brachial plexus not painful. The serratus muscle only a little atrophied, the faradic and galvanic excitability of the muscle and its nerve moderately lowered. Electrical treatment: the galvanic current through the long thoracic nerve to the muscle; local faradisation of the muscle. After a short period of treatment distinct improvement, both subjective and objective. After $2\frac{1}{2}$ months the arm could be easily raised to an angle of 120°, and the electrical excitability had improved. Further treatment did not effect complete recovery.

62. *Observation by Duchenne. Paralysis and Atrophy of the Diaphragm. Cure by Faradisation.*—A mechanic, aged 25. Was suffering from general progressive muscular atrophy; attacks of great difficulty of breathing, especially in walking and on the least exertion, losing breath immediately. Reversed respiratory type on forced respiration, the epigastrium with the hypochondrium being drawn in at each inspiration and protruded during expiration. These symptoms, lasting 14 days, were referred to weakness of the diaphragm. Regular faradisation of the phrenic nerves removed the embarrassment in a few weeks; the respiration became normal again and the patient could resume his occupation.

63. *Personal Observation. Dystrophia Muscularis Progressiva (Juvenile Form).*—A man, aged 44, of large size, had noticed since

his fifteenth year that his right arm was weaker and somewhat wasted, but has always been able to use it. Only a year ago noticed increasing weakness of the different movements of the upper extremity and also a loss of power in the legs. Pain or paræsthesiæ never present. No hereditary predisposition.

Examination in November 1880 gave the following result: Weakness and atrophy of the neck muscles, trapezius and latissimus dorsi; paralysis and atrophy of both serrati; lower part of both pectorals completely disappeared. Deltoids well developed and powerful, the left decidedly hypertrophic, as also the supra- and infra-spinati. Flexors and extensors of the upper arm atrophic and paretic, especially on the right side. Muscles of the forearm (with the exception of the supinator longus) and those of the hand quite normal and well developed. The lumbar extensors on both sides of the spine extremely atrophic and paretic; corresponding lordosis of the lumbar vertebræ. Gait waddling. In the lower extremities weakness and wasting of the right glutei; weakness in the ileo-psoas on both sides, especially the right; paralysis and atrophy of the right tensor vaginæ femoris; weakness in the whole peroneal region on both sides, the tibialis anticus being completely paralysed; slight weakness in the crural region, especially on the right.

Sensibility, sphincters, cerebral nerves, &c., quite normal. Electrical irritability in the atrophied muscles extremely lowered; no trace of RD. Galvanic treatment: Galvanisation of the back, along the spinal column; also energetic peripheral galvanisation of the affected muscles and their nerves. Unexpected improvement, movement carried out with some force after a few months of treatment; patient greatly pleased with the result, as he can work diligently and continuously, as before. Of course no sign of cure of the old-standing persistent changes.

With regard to the *methods of electrical treatment*, I would refer you to the general rules, according to which you can easily deduce what is necessary. The treatment of the paralysing lesion may under certain circumstances be difficult to carry out; occasionally the application must be made to a neuritic or traumatic lesion in the brachial plexus, or the spinal cord must be acted upon from the cervical to the lumbar enlargement. But you will generally have to limit yourselves to the direct treatment of the paralysed (and atrophic) muscles themselves, which you may do either with the galvanic current or with the faradic, according to the rules of local faradisation. Nothing is known with regard to the reflex actions in these muscles. Powerful currents, large electrodes, and great perseverance in the treatment are mostly required. There are only a few things which may require special mention.

In *paralysis of the serratus anticus major* it is best to place the anode on the spinal column, and to stimulate the long thoracic nerve in the supraclavicular fossa (fig. 29), in the axilla, and along its course over the ribs; the muscle itself can be excited directly only with difficulty, and this may be done most easily when the arm is raised and supported.

In *paralysis of the sacro-lumbalis* the stimulation must be made, either galvanically or faradically, with large electrodes and very powerful currents, with closures and reversals; it is best to do it when the patient's body is bent somewhat backwards, in order to admit of a full contraction of the muscle.

In *paralysis of the diaphragm* a direct treatment of the muscle will not be practicable, as the current wave will hardly be strong enough to accomplish it; if you are inclined to try, the transverse passage through the region of the ribs or from the back to the epigastrium and the other origins of the diaphragm is to be recommended. (An inspiratory reflex from the skin may also be efficacious in this application.) But the best mode of procedure is to place one pole in the epigastrium or along the attachments of the diaphragm to the ribs, and to stimulate the phrenic nerves in the well-known place in the neck (fig. 29) with the other (kathode), galvanically or faradically. According to circumstances the anode may also be applied to the nape of the neck, and direct treatment of the cervical cord or of the medulla be undertaken.

Paralysis of the abdominal muscles always requires a local excitation of the muscles to all the different motor points, of which they possess a great number; the anode being on the back, the different points are to be touched successively with the kathode, so that extensive contractions may be induced

7. PARALYSIS OF THE UPPER EXTREMITY.

Hardly any other part of the body becomes the subject of electrical treatment so often as the upper extremity, and this especially because of the great frequency and diversity of its paralyses; all possible forms may occur—isolated paralysis of single muscles or of certain muscle groups, paralysis of one or another nerve region, or combined paralysis of several, going on to complete powerlessness of the whole extremity, with or without accompanying sensory disturbances, or vasomotor or trophic disorders.

These forms of paralysis are very important, because they often cause considerable functional disturbance, interfere very seriously with the calling of those affected, and oblige them to seek help early; but they are also extremely interesting on account of their various etiological relations, on account of their significance as symptoms of a whole series of important central diseases, and also on account of our advanced knowledge of their symptomatology and diagnosis, resulting from the great development of the electrotherapeutic methods.

It would indeed be very interesting to enter more fully into all these things, if the consideration of the mass of material still to be disposed of did not enjoin a considerable reserve upon me; I must therefore confine myself to a short sketch, all the more because our former general electrotherapeutical discussions make our more minute entering into details superfluous. Besides, such cases will come so often before you that you will soon acquire the necessary practice and sureness in the electrical treatment.

The *etiological factors* of this paralysis, which are principally concerned in determining the choice of the methods of application, are very various. I must premise that such paralysis of the upper extremity is a very common and daily part of the symptoms of central diseases; it plays its part in every cerebral hemiplegia; it may occur in all possible diseases of the cord, as in poliomyelitis anterior, acute, or chronic, in amyotrophic lateral sclerosis, multiple sclerosis, cervical myelitis and meningitis, &c. The *peripheral* paralyses of the upper extremity are incomparably more frequent, and are principally induced by traumatic causes, simple pressure from the outside, which often produces paralysis of individual nerve-trunks (‘sleep’ paralysis, ‘crutch’ paralysis); blows; incised, punctured, and gunshot wounds; fractures and dislocations by surgical bandages and operations; and other such conditions. A number of the paralyses of the upper extremity arise from cold, others again from neuritis of single trunks of the brachial plexus. Inflammation of the joints is a cause by no means rare, especially in the shoulder and elbow, and leads partly to neuritic paralysis, partly to muscular atrophy with corresponding paralysis, especially in the deltoid. Finally, certain forms of toxic paralysis (above all lead palsy) usually localise themselves in the nerve-muscle regions of the upper extremity.

The *symptomatology* of this paralysis, into which I cannot, of course, enter more particularly here, is determined according to the seat, the localisation, and the extent of the lesion; if the *axillary* nerve is affected, paralysis (and perhaps atrophy) of the deltoid, with its well-known effect upon the raising of the arm, is present; paralysis of the *musculo-cutaneous* hinders the flexion of the forearm (from inaction of the biceps and brachialis anticus), not completely, however, for the supinator longus, acting as a flexor, may sometimes act vicariously in a surprising manner; paralysis of the *radial* (most frequently the so called 'sleep paralysis') destroys the function of all the muscles on the extensor side of the forearm (extensors and supinators) in a very characteristic and typical manner, and, when the seat of lesion is higher up, as in crutch paralysis and dislocation of the shoulder, also the function of the triceps; paralysis of the *median* prevents the flexion of the wrist and fingers, pronation, and the action of the thenar muscles (ape hand); while paralysis of the *ulnar* arrests flexion of the hand to the ulnar side and that of the three last fingers, and involves the hypothenar muscles, all the interossei, and the adductor pollicis (impossibility of extending the two last phalanges, claw hand). In all these forms of paralysis the sensory disturbances characteristic of the nerve trunk involved and of its terminal sensory expansion may be present and contribute materially to an exact diagnosis.

Electrical examination in paralysis of the upper extremity furnishes very valuable data in many respects. In the first place the exact seat of the lesion may frequently be diagnosed from the fact that the peripheral portion of the nerve is still excitable, but not the central, in consequence of the arrest of conduction, as, for example, in paralysis from pressure on the radial nerve ; and the peripheral lesion can in this way be localised in nearly all peripheral arm paralyses, by the inexcitability of the brachial plexus in the supraclavicular fossa, provided that complete RD has not already destroyed all the excitability of the nerves. The presence of excentric sensation on excitation above and below the seat of lesion gives supplementary evidence on this point.

Electrical examination furnishes in addition the usual information about the presence or absence of grosser nutritive disturbances in the paralysed nerves and muscles, and as to the presence or absence of RD. It will inform you not only of the severity of the lesion, but also not unfrequently of its causes (e.g. in radial paralysis, where the excitability is normal if it results from pressure, whilst RD is generally complete in lead paralysis). Every possible degree of RD may be present; complete in severe traumatic and neuritic and in saturnine paralysis, as also in spinal infantile paralysis; partial in the slighter compression paralysis, in progressive muscular atrophy, and in amyotrophic lateral sclerosis; while in the very slight pressure paralyses (e.g. ‘sleep’ paralysis of the radial) and in all forms proceeding from lesions of the upper cervical cord and brain the excitability may be quite normal or may present a simple diminution, in very rare cases even a slight increase. I should have to repeat again and again what I have said in the General Part (Lects. IX. to XI.) if I were to enter into all the details, and I must refer you to my Handbook of Peripheral Nervous Diseases for the special diagnostic significance of the results of electrical investigation. I will only mention further that the electrical examination furnishes many data in respect of prognosis, and that in the same form of paralysis—as, for example, that from pressure on the radial nerve—the prognosis may be decided according to the results of the electrical examination exactly in the same way as in rheumatic facial paralysis. Compare on this point the general statement on p. 204.

Besides those already mentioned, there are a number of *combined forms of paralysis*, in which several nerve regions are involved, or in which the more or less numerous paralysed muscles belong to different peripheral nerve-regions (though still belonging to the region of some one particular root of the brachial plexus or to a definite locality in the spinal cord). To the former belong the paralyses, often very extensive, after shoulder and elbow dislocations and fractures of the humerus, and the central arm paralysis; to the latter many cases of progressive muscular atrophy (especially the juvenile form), advanced cases of lead paralysis, certain forms of paralysis after delivery, and the 'combined shoulder-arm paralysis' (in the deltoid, biceps, brachialis anticus, supinator longus and infraspinatus), first mentioned by me, which has its seat generally in the trunk of the brachial plexus made up by the fifth and sixth cervical roots (in the region of or just above the so called supraclavicular point; vide fig. 29), and sometimes in the corresponding section of the anterior grey cornua of the cord. The remarks already made on the symptoms and electrodiagnosis of arm paralyses hold good also for all these combined forms.

I may restrict myself here to citing a few instructive cases, and merely refer to the examples belonging to this category already mentioned in previous lectures [cf. Obs. 5, 6, 8–12, 15 (cases of paralysis of the upper extremity from cerebral disease); Obs. 34 (poliomyelitis ant. chron.); Obs. 35 (progressive muscular atrophy); Obs. 37 (ulnar paralysis); Obs. 38 (combined shoulder-arm paralysis); Obs. 39 (paralysis of the deltoid); Obs. 40 (paralysis after humeral dislocation); Obs. 41 (radial paralysis)].

64. *Personal Observation. Isolated Paralysis of the Left Musculo-Cutaneous Nerve.*—A porter, aged 37, on getting up on May 29, 1881, noticed numbness on the flexor side of the left arm, and weakness of the same arm, although its individual movements could still be carried out. Cause unknown; patient does not know whether he slept lying on the arm. Condition on June 3: Only symptom great difficulty in flexing the left forearm, which can only be done by very energetic contraction of the supinator longus; biceps and brachialis anticus completely paralysed and flaccid. Coraco-brachialis found on careful investigation to be normal. Distinct blunting in the forearm of the senses of touch, pressure, temperature, and position, limited

to the region corresponding to the expansion of the lateral cutaneous nerve; everything otherwise normal. On electrical examination on the right side normal contraction of all the muscles concerned, effected from the supraclavicular point; on the left side only the deltoid and supinator longus contract from that point, the biceps and brachialis anticus remaining perfectly flaccid even with a strong current. Partial RD appeared subsequently in the flexors of the upper arm. Galvanic treatment to the suspected seat of lesion, then stimulation from the supraclavicular point and peripheral galvanisation of the muscles. Improvement soon appeared, which made regular progress, so that the patient was cured and able to work after 8 or 10 weeks. On a subsequent examination (in March 1882) everything entirely normal; on excitation of the supraclavicular point, on the left side, all the flexors of the forearm contracted well.

65. *Personal Observation. Traumatic Paralysis of the Left Median and Musculo-Cutaneous Nerves.*—A soldier, aged 24. Wounded on August 4, 1870, at Weissenburg; course of the shot from the anterior half of the left deltoid to close below the point of the left scapula behind; in consequence anæsthesia and paralysis in the whole median region in the forearm and hand, beginning with severe pain; also paralysis of biceps and brachialis anticus (internal half). On October 8, 1870, paresis in the muscles mentioned still very great, with numbness and diminished sensibility in the median region of the hand. Moderate amount of muscular atrophy, great pain on pressure. RD complete in the median region, partial in the biceps. Galvanic treatment to the supraclavicular region, and then the kathode labile over nerves and muscles; immediately afterwards improvement in motility. 4th sitting: After the electrisation hand warm, improvement greater, motility of the ball of the thumb distinctly better. 6th sitting: Motility of the biceps really improved. 14th sitting: Sensibility of the fingers completely re-established; now only traces of numbness. Flexors of forearm act well. No very great improvement in median region. Discharged after 21 sittings.

66. *Personal Observation. Paresis of the Right Ulnar Nerve.*—A porter, aged 34. Similar affection a year ago (anæsthesia of the hand and forearm, weakness of the hand); cured in a few sittings by the galvanic current. For 3 days, without any known cause (sleep paralysis?), numbness, anæsthesia, and weakness in the right hand. Sensibility greatly diminished in the regions of the median cutaneous in the forearm and the ulnar in the hand. Motility enfeebled in the whole ulnar region. Otherwise everything normal. Galvanic treatment: Anode on the ulnar nerve above the elbow,

kathode stabile and labile through the skin and muscles. After a short application sensibility returned under the anode, and, on moving it downwards along the forearm, gradually at each place touched; motility also appeared improved after the sitting. Next day sensibility normal as far as the wrist; flexion of three last fingers stronger. After 3 more days complete cure.

67. *Personal Observation. Crutch Paralysis of the Right Radial Nerve (Traumatic Paralysis of the Sciatic Nerve).*—A French soldier, aged 25. Wounded on August 4, 1870. Gunshot wound of the knee; entrance near the patella in front, exit posteriorly in the middle of the thigh in the sciatic region; paralysis of the whole sciatic region, complete RD.

On September 24 began to walk a little with crutches, noticed after some time increasing weakness of the right hand, especially in extensors; after 8 or 10 days no longer possible to hold crutch. Condition on November 4: Complete paralysis of right radial region, including triceps. Paresis in region of median and ulnar nerves. No disturbance of sensibility worth mentioning. Electrical irritability of paralysed nerves and muscles completely intact, but absence of contraction in extensors of forearm from excitation of supraclavicular point. Treatment: Anode on brachial plexus, kathode labile; closures and reverses of the current through the nerves and muscles. Some improvement immediately. November 7. Triceps much improved, hand raised to horizontal position. November 16. Cure almost complete; all movements possible, only with less force than normal. December 5. Completely cured.

68. *Personal Observation. Sleep Paralysis of the Radial Nerve.*—A factory worker, aged 42. Came to the policlinic with the history of having slept on the right arm during the night and having noticed paralysis of the hand in the morning. Paræsthesia in the radial region of the thumb. Examination showed complete paralysis of the radial region of the forearm; triceps unaffected. Objective sensibility not disturbed. Electric irritability normal, but no contractions induced from axilla and supraclavicular fossa. Slight traces of contraction in the supinator longus on great exertion. Treatment: Kathode stabile on the seat of pressure; distinct improvement immediately. Then stimulation with the kathode in the supraclavicular fossa; again improvement, as also when the nerve and the muscles were afterwards thoroughly treated with the kathode labile. On the following day distinct improvement, which advanced still further after galvanic treatment. Patient cured at the end of a week.

69. *Personal Observation.—Sleep Paralysis of the Radial Nerve.*

—A waterworks overseer, aged 25. Acquired a paralysis of the left arm on September 10, 1872, by lying on the edge of the bed. On October 11 still complete paralysis of the radial on the left side. Skin over thumb and back of hand somewhat numb, with diminished sensibility. Electric excitability intact; but contractions not induced in radial region either from axilla or supraclavicular region, easily accomplished on the right side. Galvanic treatment. Patient could immediately raise hand to horizontal position. October 12. Considerable improvement; faradisation to-day; renewed improvement. October 13. Improvement; galvanic treatment. October 24. Discharged nearly cured; all movements possible, if not with complete force. Strong contractions in the radial region induced faradically from the axilla. Admitted again after 8 days, on account of failure of strength from hard work; all movements possible, but with less power than normal; further treatment for 4 weeks necessary to restore the normal power.

70. *Personal Observation. Traumatic Paralysis of the Radial Nerve.*—On March 10, 1881, fracture of the arm and forearm. Radial paralysis observed on removing the bandages; great formation of callus on the upper arm. In the beginning of May callus chiselled away, radial nerve freed; thin in callus and below it, thickened above. Condition in the middle of September: Complete paralysis of the whole radial region of the forearm. Complete RD. Diminution of sensibility on the dorsal surface of the forearm. Slight flexure contraction. Galvanic treatment of the seat of lesion and of the muscles, beginning in the end of September. October 13. Active movements distinct, with less power, but considerable as to extension. Sensibility improved. Faradic and galvanic excitability of the radial from above the lesion restored; still RD in muscles. Improvement made rapid progress from that time.

71. *Personal Observation. Combined Shoulder-Arm Paralysis* (*Erb*) *after Injury.*—A baker, aged 38. Ten days ago fell down a flight of steps on the outstretched left arm and left shoulder. Immediately after could not move the arm well, and had numbness in region of shoulder and upper half of arm. Condition on July, 20, 1867: Complete paralysis of the left deltoid, biceps, and brachialis anticus. Triceps and forearm muscles (supinator longus?) normal. No objective disturbance of sensibility. Complete RD in the paralysed muscles in the course of the following days, especially in the deltoid. Galvanic treatment: Anode on plexus and cervical cord, kathode labile over the paralysed nerves and muscles. Improvement in the forearm flexors after a few days, progressing slowly.

Deltoid remained paralysed and atrophied rapidly. Patient had to be discharged after 22 sittings; motility in biceps and brachialis anticus improved, deltoid still completely paralysed. (Spontaneous improvement began after 6 weeks in this muscle, leading to final cure.)

72. *Personal Observation. Combined Shoulder-Arm Paralysis from Neuritis of the Brachial Plexus.*—A nail-maker, aged 17. Two months ago paræsthesia in the left thumb and index finger; diminution of sensibility and weakness of movement in these fingers; after 14 days paralysis also in shoulder and arm. Since then all symptoms stationary. Condition on December 1, 1866: Left arm only affected. Complete paralysis of deltoid, biceps, brachialis anticus, and supinator longus, probably also of supinator brevis, with paralysis of the median region in the forearm and hand; all other muscles normal. Subjective, but no objective disturbance of sensibility in the median region of the hand. Electrical examination (according to the full description made in 1866) showed partial RD, in various stages of development, in the paralysed muscles, the deltoid being most affected. Galvanic treatment: Anode stabile on the brachial plexus, kathode labile and KC on all the paralysed nerves and muscles; three times a week. Distinct improvement in the forearm flexors even after the fourth sitting. After the sixth sitting increased improvement; movements very distinct in supinator longus and in median region. After tenth sitting flexion of forearm quite restored; motility of the flexors of the fingers, thenar muscles, and also supinator much improved; deltoid also acting. Improvement advanced regularly with little variation, and after 30 sittings recovery could be called complete.

73. *Personal Observation. Traumatic Paralysis of the Radial, Median, and Ulnar Nerves.*—A French soldier, aged 38. Wounded on August 4, 1870. Gunshot fracture of the right arm, in the upper third. Came under my observation on November 4, 1870, after complete healing of the wound and of the fracture. Complete motor and sensory paralysis of the forearm and of the hand, the indicator muscle being the only one acting. Complete RD in the radial nerve and the muscles supplied by it, faradic and galvanic excitability fairly well preserved in the median and ulnar regions. Better prognosis, therefore, for the two last-named nerves, confirmed by the fact that immediately after the first galvanic treatment (anode on the neck, kathode labile to the periphery, &c.) the sensibility returned to the skin supplied by the median and the ulnar, whilst at the same time small movements (previously impossible) could be made with the flexors. Rapid progress of this improvement during the following days, and weak movements in the radial region also from November 7. Some

hindrance to the movements from stiffness of the joints, but regular advance of the improvement.

The *method of the electrical treatment* of these forms of paralysis is, of course, founded principally on as exact a diagnosis as possible of the position and nature of the paralysing lesion, and accordingly the choice of the first application—to the seat of lesion—must be made. Thus in cerebral paralysis the application should be made to the head and the sympathetic (vide Lects. XVI. and XVII.), in spinal paralysis the cervical cord and the sympathetic should be treated (Lects. XIX. and XX.), and in peripheral paralysis (Lect. XXI.) the neuritis, the traumatic lesion, the shoulder-joint affection, the cicatrices, pressure points, &c., in the way already known. For pressure paralysis of the radial nerve, which is so frequent and interferes so much with the use of the hand, I would mention here the statement of E. Remak that in many cases a most beneficial effect, often shown by an increase of motility during the passage of the current, may be attained by a stabile action of the kathode with a carefully chosen and moderate strength of current. I can confirm this for some cases, although only for those which are very slight or which have already begun to improve (vide Obs. 61); but I have generally been unable to see such an immediate effect; and it appears to me to result more from a fortunate selection of cases than from the method of application and the strength of the current.

In the second place the *direct antiparalytic treatment* must be attended to, which can often be done very profitably on the upper extremity, especially in cases of peripheral paralysis. You will often, indeed, find it possible to let the electric current act centrally to the seat of lesion, and thereby break through the obstacle to conduction. It is advisable, therefore, to try this in all suitable cases, and, in all peripheral paralyses at least, to set up a strong stimulation from the nerve trunks in the axilla, or, still better, in the supraclavicular fossa. In any case, in view of the fulfilment of all the indications with which we have here to do (for the direct antiparalytic action, for the removal of the finer and grosser nutritive disturbances in the nerves and muscles), the nerve trunks and the muscles should be subjected to electric stimulation in their whole extent and in a sufficient manner, according to the known methods of local faradisation (figs. 30 and 31); and this holds good for central as well as for peripheral paralysis. It is difficult to decide whether reflex actions also play their part in this, but it is certainly not unlikely; at all events in paralysis of mixed nerves the peripheral stimulation of the nerve twigs and of the skin will help somewhat in the removal of the sensory obstruction, and may also have a reflex action on the motor tracts and on the obstruction in them.

It would be superfluous to enter further into the separate forms of paralysis; the modifications of the application necessitated by the localisation of the paralysis will be determined by the region affected.

I will only mention that, if contraction of the antagonistic muscles is present at the same time (as in cerebral hemiplegia, spinal infantile paralysis, &c.), overpowering that of the paralysed muscles, it is advisable to remove this contraction first, either by electricity or mechanically, and only then to stimulate the paralysed muscles; by the approximation of their points of insertion they can be more easily and thoroughly drawn together, which is necessary for their restoration.

The *results* of this treatment correspond naturally, to the causes of the paralysis, and are, consequently, very various, sometimes rapid and complete, sometimes tardy and incomplete, often wanting altogether; they are most favourable in paralysis from pressure and compression, not unfavourable even in severe traumatic paralysis, very good in neuritic cases, and much less satisfactory in spinal and cerebral paralyses. Details are unnecessary; you will see after a short time whether the cure is to be rapid or slow, and in any case the treatment must be carried out with the greatest perseverance.

8. Paralysis of the Lower Extremity.

The conditions are comparatively more simple in paralysis of the lower extremity than of the upper, although the symptom occurs there frequently, in many varieties and combinations—isolated paralyses of individual muscles and individual nerves, and various combined forms up to total paralysis of one and often even of both lower extremities (paraplegia). Paralysis of a central and above all of a spinal origin is of most importance in the lower extremity; whilst cerebral paralysis, in spite of its great frequency (in hemiplegia, &c.), tends to remain in the background, because it improves with comparative rapidity to a moderate restoration of function, and is, therefore, not so severely felt by the patient.

Almost all diseases of the spinal cord lead to motor weakness advancing to marked paralysis of the lower extremities: the different forms of myelitis, especially acute and chronic poliomyelitis, sclerosis, acute ascending paralysis, progressive muscular atrophy (especially in the crural region), compression and concussion, meningitis, &c.; and almost all these forms frequently become the subjects of electrotherapeutical experiments.

The long peripheral course of the nerves involved, however, inside the vertebral canal, in the pelvis, and in the extremity itself, occasions the possibility of many causes of peripheral paralysis: fractures, dislocations, inflammation and caries of the vertebræ, lesions of the pelvis and of the pelvic organs, mechanical interference in difficult confinements, and the like may give occasion for it; all the mechanical and traumatic influences which affect the nerve trunks in the extremities themselves, as well as inflammatory, exudative, and other processes originating in the large joints, are frequent causes of such paralysis; and, finally, neuritic affections of these nerves (rheumatic, neuralgic neuritis, after acute diseases, &c.) may be mentioned. All these lesions may be accessible to electrical treatment in very varying degrees. When I mention, finally, that in the so called pseudohypertrophy of the muscles, and also in the much rarer true muscular hypertrophy, the lower extremities are, as a rule, involved in the paralysis, you will have a pretty fair picture of all that may occur in this connection, and that may become the subject of electrical treatment.

It is not my intention here to enter more fully into the symptomatology of these separate forms of paralysis; it may only be mentioned that in paralysis of the crural nerve the flexors of the hip joint (ileo-psoas, &c.) and the extensors of the leg (quadriceps, &c.) are affected chiefly; this may occur in an isolated way, especially in psoas affections and in acute anterior poliomyelitis; partial paralysis and atrophy in the domain of this nerve is often seen in progressive muscular atrophy, especially in its juvenile form. Paralysis in the region of the obturator nerve affects principally the abductors of the limb, and is on the whole rare. Paralysis in the domain of the gluteal nerves specially affects abduction and rotation, and fixation of the pelvis in walking and standing; it is most frequent in progressive muscular atrophy and in pseudohypertrophy. The most common form of paralysis is that of the sciatic, which affects either the whole trunk or one of its two principal branches —the peroneal nerve and the anterior muscles of the leg, or the tibial and the calf muscles—and which is very easy to recognise. Nearly all spinal paralyses begin in this very nerve region, and the great length and exposed situation of the nerve cause the greater frequency of peripheral lesions in it.

In most cases you will be able to draw exact diagnostic conclusions as to the position and nature of the lesion from the extension of the paralysis in the muscles, and from the accompanying sensory, trophic, and reflex disturbances.

The *electrical examination* is useful only in a limited degree; and particularly for the determination of the seat of peripheral paralysis it is of little service, because great tracts of the nerves concerned (inside the pelvis or the vertebral canal) are not available for direct electric excitation. For the rest the same alterations in the electrical excitability that we have already described so often occur in this paralysis, and the usual conclusions, especially in respect to the severity of the lesion, the consequent trophic disturbances, and the prognosis, are to be drawn from them. With your conclusions in regard to the seat of the lesion, on the other hand, you must be very cautious; the electrical examination does not, as a rule, furnish any decision whether the lesion is of a peripheral, spinal, or cerebral origin. If RD is present, indeed, you may exclude with certainty a cerebral localisation, but normal electric excitability does not by any means speak for this, as it occurs also in spinal paralysis; still less can you decide with certainty on a peripheral seat of the lesion from the presence of RD, for you know that it occurs in very many spinal paralyses; other symptoms are to be taken into account; and it must specially be noticed that RD without any disturbance of sensibility and without trophic cutaneous disturbances is pretty certainly indicative of a spinal origin. You may also observe partial RD in the lower extremities (middle form of chronic poliomyelitis, certain peripheral paralyses, progressive muscular atrophy, &c.); in true and false muscular hypertrophy, however, as well as in the juvenile form of progressive muscular atrophy, only a simple diminution of the electrical irritability is present, without any qualitative alteration.

I will only cite shortly a few examples of leg paralyses, while reminding you of the observations already given—5, 6, 7, and 11 (cerebral paralysis), 18 to 22, 32 to 34 (spinal paralysis), and 45 (peripheral paralysis)—and referring you to the observations yet to come, 82 to 84 and 86 to 88.

74. *Personal Observation. Paresis of the Crural Nerve (Chronic Neuritis ?).*—A merchant, aged 39. Had suffered for about a year and a half from acute pains in the left hip and buttock, extending to the knee, but gradually abating. For the same period a feeling of heaviness in the left leg, increasing in the last few months to distinct weakness. Four weeks ago, after great exertion, severe pain in the whole left leg, especially in the anterior surface of the leg, combined with trembling of the limb; since then much weaker, and decided wasting. Otherwise healthy. Condition in April, 1869: Left thigh distinctly wasted and more flaccid than the right; weakness of the left quadriceps. Numbness of sensibility on the anterior internal surface of the leg below the knee. Circumference of the left thigh about 2 to 4 centimetres less than the right. Electrical excitability diminished to a small extent. Galvanic treatment: Stabile currents through the spinal column; then K labile through the nerves and muscles and over the anæsthetic portion of the skin, A being on the sacrum. Distinct improvement even after 4 sittings; pain in the leg nearly disappeared; numbness and weakness of the leg less. After 8 sittings decided relief; leg stronger, walking easier, numbness less. By the end of May continued and marked improvement; circumference of left thigh increased 1½ centimetre, strength of the leg considerably greater, numbness almost disappeared. By the end of August treatment concluded, after 65 sittings.

75. *Personal Observation. Paresis of the Right Sciatic Nerve. Hypertrophy of the Crural Muscles.*—A tinsmith, aged 43. Had been

treated twice before for the same affection, and speedily cured by electric brushing. Now came for the third time, complaining of weakness in the right foot and leg, with coldness and formication in the foot and in the calf. Condition in November 1873: Limping with the right leg, the foot resting only on the heel. Standing on tiptoe impossible on the right side, easy on the left. Marked paresis of the right calf muscles, weakness also in the peroneal region and in the muscles at the back of the thigh. Crural region normal. No objective sensory disturbance. Right foot somewhat colder than the left. Electrical irritability unaltered. Circumference of the right calf 2 centimetres larger than the left. Galvanic treatment: 18 elements, labile, from the sacrum through the sciatic nerve. Immediate relief. So much improvement after 2 more sittings that patient stayed away from treatment.

76. *Personal Observation. Paralysis in the Territory of the Right Peroneal Nerve (Neuritis ?).*—A peasant girl, aged 26. Ill since July 1866. Menses ceased for one period, and formication, with weakness, came on in the right foot, the toes hanging down and dragging. Since remained stationary. Condition on May 18, 1867: Morbid changes only in the right leg, paresis in the peroneal region, complete paralysis only in the tibialis anticus. Calf normal. Sensibility over the whole anterior surface of the leg and on the dorsum of the foot decidedly less than on the left side. Circumference of the right calf 1 centimetre less than the left. Complete RD in the tibialis anticus on electrical examination; simple diminution of the electrical irritability in the other muscles. Galvanic treatment: Stabile and labile currents through the lower part of the back, then K labile through the sciatic and peroneal nerves and their muscles. On June 1 (after 3 sittings) raising of the right foot much improved, sensibility also somewhat better. June 28 (after 10 sittings). Greater improvement of the motility and sensibility. July 20 (after 18 sittings). Motility now almost normal; diminution of sensibility still present to a small extent.

77. *Personal Observation. Paralysis of the Left Peroneal Nerve, from the Cicatrix of a Bed Sore.*—A peasant girl, aged 19. Had a severe sloughing decubitus on the sacrum during an attack of typhoid, which only healed after discharging pus for months. Paralysis of the left foot noticed at last; paræsthesia or anæsthesia never present, but at times acute pains, radiating from the sacrum downwards along the leg in the region of the peroneal nerve. Came under treatment 3 months later. June 1873. Large, deep-sunken cicatrix on the buttock, deeper and more adherent on the left side than on the right.

In the left leg almost complete paralysis in the whole peroneal region; tibialis anticus and extensor hallucis longus entirely paralysed, the other muscles very paretic. The rest of the sciatic region, as also the crural, entirely normal. Sensibility intact in the region of the peroneal nerve. Left calf $3\frac{1}{2}$ centimetres thinner than the right. Complete RD at a late stage. Galvanic treatment: 24 elements A and K stabile through the cicatrix, then A on the cicatrix, K labile through the nerve and the muscles. Marked improvement in movement immediately after the first sitting. On August 12 discharged; improvement advanced markedly, although slowly. Excitability restored to a small extent in the peroneal nerve.

78. *Personal Observation. Traumatic Paralysis of the Left Peroneal Nerve.*—A builder, aged 34. On December 24, 1872, in a railway accident left leg was crushed at the patella, in the near neighbourhood of the head of the fibula. Immediately afterwards paralysis and anæsthesia of the left leg and foot, with the exception of the sole. Condition on January 25, 1873: Complete paralysis in the whole left peroneal region; no paralysis, but weakness, in the domain of the tibial nerve. Sensibility somewhat diminished on the dorsum of the foot, comparatively normal in the leg. Left calf 2 centimetres thinner than right. Complete RD in the peroneal region, simple diminution in the tibial. Galvanic treatment: Stabile through the seat of injury with both poles, then K labile through the muscles. First traces of motility not till the end of March, occurring in the ext. long. digit., a few days later also in the peroneal muscles. On April 9 return of the faradic irritability of the nerve above the injury, not below it. At the beginning of May motility restored to tibialis anticus, and at the end of May to the ext. halluc. long. The improvement advanced rapidly; patient discharged on July 20. Motility very good; power not yet quite normal.

The *methods of treatment* are essentially the same as for the upper extremity. The causal treatment must be directed to various parts according to the lesion which causes the paralysis, and here especially the treatment of the spinal cord comes into consideration, along with treatment of the joint affections, the peripheral nerve lesions, &c., which are to be carried out according to the well-known rules. You must pay particular attention to the proper localisation of the current in the diseased portion of the spinal cord.

The further treatment, with the direct action of the current on the paralysed nerves and muscles, is to be made according to general directions; the possibility of an energetic action above the seat of lesion is less manifest here, because the plexus is almost inaccessible to the current. Still you may try, in suitable cases, to stimulate the nerve trunks of the cauda equina inside the vertebral canal by means of very strong currents with large electrodes (KC and reversals; cf. p. 120); or attempt the stimulation of the sacral plexus from the rectum, which is easy with a rectal electrode, the other being placed either in the neighbourhood of the sacrum or on the exit of the sciatic nerve. For all these applications to the large nerve trunks of the lower extremities, especially their upper portion, large electrodes and relatively strong currents are to be recommended, as is the case with deep-lying portions of nerves. Place the anode always on the loins and the kathode on the nerves to be stimulated or on the motor points, if possible in such a way that a great part of the course of the nerve may come into the region of the densest current diffusion. You will reach the crural nerve best in the groin, and the sciatic just below the gluteus maximus, and you may energetically influence its whole course along the posterior surface of the thigh, by drawing the kathode briskly up and down between the higher point and the patella. At the knee itself you may likewise stimulate the peroneal and tibial nerves (fig. 33) with the greatest ease, and induce contractions in the muscles supplied by them. In cases where the nutrition of the muscles requires special consideration you will add to this a thorough faradic or galvanic excitation of the muscles concerned, according to the usual rules.

To conclude, reflex action may be made use of much more thoroughly in the lower extremity than in the upper, for the reflex functions here are much more direct and easier to bring to light than in the upper limb; especially from the sole of the foot, the dorsum, the anterior and internal surfaces of the thigh and the neighbourhood of the groin the most diverse reflexes may be induced, which under certain circumstances (according to the general rules previously given; vide p. 432 et seq.) may be used for the treatment of the paralysis. You will seldom find it necessary to have recourse to faradic brushing of the skin at the points mentioned (particularly the sole and dorsum of the foot and the internal surface of the thigh); it may be useful under certain circumstances, but generally the ordinary (faradic or galvanic) irritation of the nerve trunks and the labile excitation of the skin with moist electrodes are sufficient for this purpose.

For the duration and intensity of the several applications, and the frequency of their repetition, the ordinary principles and rules hold good here, as for the upper extremity.

The *results* of the electric treatment depend here also, of course, principally on the cause of the paralysis. The frequent occurrence of severe spinal diseases often makes the electrotherapeutics of these paralyses a very thankless, profitless task. On the other hand, however, you will often be compensated by great results in chronic anterior poliomyelitis, less often in acute, in traumatic, neuritic, arthritic, rheumatic, and pressure paralysis, but very great caution and untiring perseverance are often required.

LECTURE XXV.

Electrotherapeutics of the Separate Forms of Paralysis (*concluded*)—9, Paralysis of the Velum Palati and the Fauces—Paralysis of Deglutition—Pathogenesis—Separate Cases—Methods of Treatment—10, Paralysis of the Laryngeal Muscles—Paralysis of the Vocal Cords—Character and Methods of Treatment—Percutaneous and Endolaryngeal Application—Results—11, Paralysis of Respiration—Artificial Respiration—Rhythmical Faradisation of the Phrenic Nerves—12, Diphtheritic Paralysis—Pathogenesis and Symptoms—Cases—Electric Treatment—Results—13, Lead Paralysis and other Toxic Forms—Characteristics of Lead Paralysis—Electrical Irritability—Seat and Nature of the Disturbance—Methods of Treatment—14, Muscular Atrophy and Muscular Hypertrophy—Pure Muscular Atrophy—Atrophy in Joint Affections—Cases—Treatment—Muscular Hypertrophy—Myotonia Congenita.

9. Paralysis of the Velum Palati and Fauces. Paralysis of Deglutition.

Such occurrences are not very rare, and they may become the subject of electrical treatment on account of the duration and obstinacy of the affection.

Paralysis of the velum palati—which betrays itself by nasal speech, difficulty in pronouncing certain letters, disturbance of swallowing and regurgitation of fluids through the nose; by immobility on vocalisation, abnormal position and asymmetry of the soft palate and uvula; and by the absence of reflex action on touching the parts—may occur on one or both sides, either limited to individual muscles or extending over several or all of them. It is often an accompaniment of disease of the facial and of the trigeminus at the base of the skull, or a sequel of diphtheria, or an accompaniment of bulbar paralysis, and occasionally even of cerebral hemiplegia.

Paralysis of deglutition, caused by paresis and paralysis of the œsophageal fibres, is sometimes an accompaniment of cerebral paralysis, but most often either a sequence of diphtheria faucium or a symptom of bulbar paralysis; it shows itself by difficulty or impossibility of swallowing, swallowing 'the wrong way,' and failure of strong reflex contractions on mechanical irritation of the walls of the fauces.

These disturbances are generally not difficult to recognise, but it is often difficult or even impossible to estimate accurately the degree in which the different muscles and nerve provinces are involved in the paralysis.

Even *electrical examination*, which has to contend with many difficulties in these parts, but which is often much facilitated by the simultaneous anæsthesia and absence of reflexes, does not give much help in this direction, as the isolated stimulation of individual muscles can only very imperfectly be carried out. In many cases nothing abnormal is to be found, in others we may demonstrate simple diminution of irritability (bulbar paralysis), while in others again RD may be observed (e.g. in diphtheria, as Ziemssen first pointed out). Certainly the direct electrical examination of the faucial muscles has not often been tried, but the reflex movements of deglutition (p. 122) may be embarrassed or prevented altogether in paralysis of these muscles, so that much stronger currents are necessary to excite reflex contractions in cases of progressive bulbar paralysis.

A few cases may serve as examples for the treatment and its results.

79. *Personal Observation. Paresis of the Velum Palati.*—A girl, aged 7. Signs of the disease from early childhood. Speech decidedly nasal; cannot pronounce certain letters, especially *s*, *c*, *x*, &c.; because air escapes through the nose, and the *s* sounds almost like *n*. Slight paresis of the soft palate on examination; escape of fluids now and then through the nose in drinking. Diphtheria never present. Child otherwise healthy. Treatment at first: The galvanic current transversely through the anterior aural region, and longitudinally from the nape of the neck to the cheeks and the floor of the mouth. Gradual improvement. Later also direct *faradisation* of the soft palate, and finally systematic practice of the much-improved pronunciation of the letter *s*. Cure after 50 sittings.

80. *Observation of M. Rosenthal. Diphtheritic Paralysis of the Velum Palati, the Tensor Choroideæ, and the Sphincter Pupillæ.*—A chambermaid, aged 22. Had had diphtheria of the fauces; suffered from difficulty of swallowing, frequent regurgitation of fluids, indistinct nasal speech; the right half of the soft palate paretic. Paresis of accommodation; right pupil dilated, reaction bad. Reflexes from palate and throat greatly diminished. Electrical examination showed RD. Local galvanic treatment and excitation of movements of deglutition removed the nasal speaking and the difficulties of swallowing in less than a week.

81. *Personal Observation. Diphtheritic Paralysis.*—A shoemaker, aged 25. Angina diphtheritica from June 29 till July 12, 1867. A few days later renewed difficulty in swallowing, but without pain; regurgitation of fluids through the nose. Also a certain weakness and trembling in the limbs, diminution of visual power; speaking embarrassed and slightly nasal. Condition on July 18: No ulceration or cicatrix in the fauces. Motility of the soft palate in vocalisation pretty good, right half somewhat incomplete. Sensibility greatly diminished even for the faradic current; reflex irritability completely wanting. Faradic and galvanic excitability of the palatal muscles much diminished. Entrance of fluid into the nose in drinking; deglutition embarrassed. Sight worse than before, especially distant vision; no apparent anomaly in accommodation for near vision. Some difference in the pupils, reaction tardy. Galvanic treatment: Transverse through the cheeks to the sympathetic in the neck, and direct treatment of the soft palate with the kathode. Decided improvement after the fourth sitting. Entrance of fluids into the nose not so frequent; vision better; extremities stronger. After the sixth sitting no more regurgitation into the nose; swallowing improved. Slight relapse again in the following week; hoarseness and

weakness of the voice. Then again improvement. Treatment very irregular. Discharged on September 2, after 18 sittings, in pretty good condition. More weakness in the extremities came on a little later; subsequently complete cure.

Compare further Observations 16 and 17, for difficulties of deglutition in consequence of Bulbar Paralysis.

The *method of treatment* of this paralysis is first to be chosen with regard to the lesion which causes it, and it may, therefore, be the applications suitable for bulbar and cerebral diseases, for facial paralysis, &c. In diphtheritic paralysis you may galvanise transversely through the region of the soft palate and the fauces (through the cheeks in front of the ear or through the auriculo-mastoid fossæ), stabile, for a few minutes.

For *paralysis of the soft palate* direct faradisation or galvanisation of the velum may be employed, by means of which direct stimulation of the paralysed muscles, as well as reflex irritation of them, will be accomplished. For this purpose you employ a suitable electrode, catheter-shaped, isolated as far as the tip, with a small round knob, covered with fine sponge or with wash leather; and an arrangement for interrupting the current is useful (pharyngeal and laryngeal electrode, fig. 39). With this you may touch the uvula, the pillars of the fauces, and the surface of the velum at the different points, and by means of the interrupter may open and close the circuit at will. This must be done with the mouth wide open and taking a deep breath, the current being strong enough to

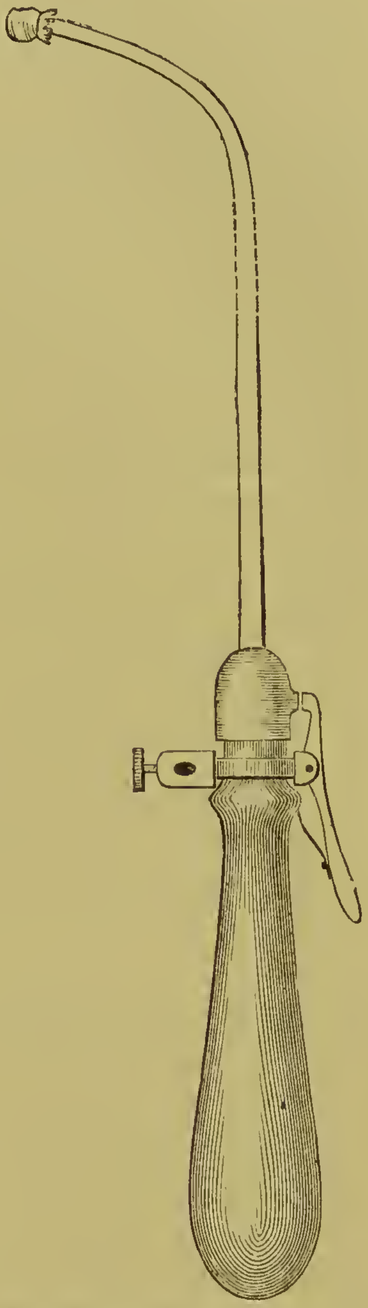

FIG. 39.—Electrode for throat and larynx, insulated to the tip and furnished with an interrupter.

induce strong contractions in the tongue and the muscles of the lips (from the mucous membrane) if these cannot be induced in the soft palate. The anode must, at the same time, be on the nape of the neck, and the application may last from 1 to 3 minutes.

For *paralysis of deglutition* you may stimulate the pharynx and the pharyngeal muscles directly and reflexly with the same electrode, but, as this is generally a somewhat disagreeable proceeding, it is more convenient and more sure to induce reflex movements of deglutition from the throat externally, with the methods already given (p. 122.) You will generally need a somewhat greater strength of current for these patients than for the healthy, and you must, therefore, increase the current until every KC or labile action of the K is followed by a visible or audible movement of deglutition. You will induce about ten such movements in each sitting, and, as the muscles are easily tired in bulbar paralysis, in order to avoid overstrain, it is advisable not to allow the individual acts of swallowing to follow very quickly upon one another, but always to make a few seconds' pause between them.

The *results* of this treatment depend essentially on the fundamental cause, and are, therefore, generally minimised, or at most palliative, in bulbar paralysis; in other forms, on the other hand, especially in diphtheritic paralysis, they are more brilliant, though very obstinate cases sometimes occur.

10. PARALYSIS OF THE LARYNGEAL MUSCLES AND VOCAL CORDS. PARALYTIC APHONIA AND DYSPHONIA.

The more recent investigations of laryngeal affections have taught us to recognise the great frequency of paralytic conditions in the laryngeal muscles, which may occur isolated or in various combinations, and may result from a great variety of causes. This is a department which lies almost entirely within the sphere of laryngologists; only a scanty material for observation, therefore, remains at the disposal of neurologists and electrotherapeutists, and I will limit myself to what is most necessary and to what belongs purely to electrotherapeutics. In the choice of remedial measures it must necessarily be decided first of all where the paralysing lesion is situated, whether it is in the laryngeal muscles or their nearest motor twigs themselves (as in catarrh, ulceration, new growths, cold, over-exertion), or in the laryngeal nerves, which may be affected in the greatest possible variety of ways (diphtheria, generally affecting the superior laryngeal, neuritis, compression from tumours, goitre, aneurisms, injuries, operations, cicatrices, &c.), or in the trunk and the roots of the vagi and the accessorii (diseases of the spinal column, tumours at the base of the skull or in the neck), or, finally, in the central organ itself (bulbar paralysis, hæmorrhage into the medulla, pons, &c.) This localisation of the lesion is often easy to determine, but sometimes extremely difficult, even after the most careful investigation. In many cases, as particularly in hysterical paralysis which is so frequent and so favourable for electrotherapeutics, and in the rare toxic and intermittent paralyses of the vocal cords, we are still quite in the dark as to where the lesion is situated, though probably this is in favour of the central organs.

With reference to the symptoms, I will only mention that a lesion of the superior laryngeal nerve shows itself by paralysis of the muscles of the epiglottis, insufficient closure of the glottis, paralysis of the cricothyroid muscles, and anæsthesia of the upper half of the larynx, while a lesion of the inferior laryngeal produces paralysis of all the other laryngeal muscles and anæsthesia of the lower half of the larynx. This paralysis may be on one or both sides; it may affect the whole recurrent nerve, or only individual twigs and individual muscles, and hence may result very different laryngoscopic and symptomatic conditions. The most frequent and most important is the complete one-sided paralysis of the recurrent nerve, and among the isolated muscular forms the double-sided paralysis of the posterior crico-arytenoid muscles and the very common paralysis of the internal thyro-arytenoid, the muscles proper to the vocal cords. You will find more minute details in the handbooks of laryngeal diseases, especially in Ziemssen's work.

The electrical examination of the laryngeal muscles and nerves is in most cases impracticable. Even Prof. Ziemssen, who has certainly the greatest experience in the matter, reports that he has succeeded only in very few cases in testing the electrical excitability, and that when he has done so he has found normal as well as diminished irritability, and also RD. I have myself found diminished excitability in a few cases, on stimulating the paralysed recurrent nerve.

For the choice of the *method of treatment* the real situation of the lesion must again be considered, and the first points of application selected accordingly (transversely through the mastoid processes, through the brain, the cervical cord, &c.; application of one or both poles on the part which may be compressed by the cicatrix, neuritis, &c., in the peripheral course of the nerve); this will be determined from the diagnosis, according to general rules. Generally, however, this will not be sufficient; moreover we are, in many cases, quite in the dark as to the real seat of the lesion. It is then justifiable to set the direct antiparalytic influence of the electric current at work on the whole nervous and muscular apparatus of the larynx. It appears to be most advisable, considering our uncertainty as to the exact localisation of the lesion, to subject the muscles, as well as their nerves, the laryngeals, and the vagus and accessory, to the electric stimulation in their whole available extent. Everyone is not of this opinion, however; on the contrary, it is customary to let the current act directly on the larynx alone, by passing it through it percutaneously or by applying it directly to the paralysed muscles themselves, by means of a single or double laryngeal electrode internally. This latter proceeding is even regarded as specially rational, although it limits the stimulation to the muscles themselves and their nearest nerve twigs. I doubt, gentlemen, whether you would consider it very rational, after our general discussions, to limit yourselves to the faradisation of the small muscles of the hand in a paralysis of the ulnar nerve, whose exact seat was unknown to you; and I at all events regard this proceeding as *not* rational. It is exactly the same with internal electrisation in laryngeal paralysis. This procedure could only be of service in cases where the lesion was in the muscle itself, or in its nearest nerves, but would fail in its purpose in most other cases; and although it is sometimes not entirely ineffectual this must probably be attributed rather to the extreme reflex action which is the inevitable consequence of this somewhat cruel proceeding than to the local excitation of the individual muscles.

As the first method to be tried in all cases I would recommend to you the percutaneous stimulation of the larynx and all its nerves. This may be done with either galvanism or faradism. With the *galvanic current* you place the anode high in the nape of the neck, in order to be as near as possible to the origin of the vagus and accessorius, while you pass the 'small' or 'middle' kathode labile upwards and downwards, with firm pressure, along and close up to the larynx and trachea, and on all the places named, laterally and anteriorly, make repeated KC. This should be done on both sides for one or two minutes; by this means the vagus and the superior and inferior laryngeals fall into the region of the densest current diffusion, and they certainly reach also to the larynx and its muscles, as is evidenced by the very intense perception of taste, and the movements of deglutition which are induced reflexly from the superior laryngeal. If you wish to stimulate the larynx itself very energetically you place both 'medium' electrodes laterally on both sides and make repeated closures and reversals. From 8 to 10 or 12 elements are generally quite sufficient for this purpose.

With the *faradic current* you make exactly the same application, the anode on the nape of the neck, the kathode ('small' or 'fine' electrode) at the angle of the lower jaw, at the side of the trachea below the cornu of the hyoid bone (superior laryngeal), and farther down along the trachea, pressed deeply in (inferior laryngeal); finally on the trachea itself and transversely through it, with very strong currents.

It is beyond a doubt that in this way an energetic excitation of the nerves concerned is possible; Gerhardt has established the fact for the superior laryngeal nerve, and made it at least likely for the inferior; and I myself have been repeatedly convinced (when I busied myself with this matter many years ago) that in many persons the recurrent laryngeal may be excited by means of the faradic current by pressing the electrode firmly alongside of the trachea, especially on the left side, with a strength of current sufficient to stimulate the recurrent nerve and to produce visible energetic contractions of the corresponding half of the trachea. Certainly this is not the case with everyone; a thick layer of adipose tissue, swelling of the thyroid, great sensitiveness of the skin, &c., may interfere with the effect. From the side of the trachea also, vigorous contractions of the tracheal muscles may be set up, with strong currents and not too small electrodes, in many individuals. Rossbach has come to the same conclusion from his new investigations on this subject. He found the recurrent nerve easily stimulated by the galvanic as well as by the faradic current, and he has, therefore, established a very valuable basis for the percutaneous electrisation of the trachea and its nerves.

If this proceeding should not answer the purpose—in some exceptional cases you will leave it out altogether—you will proceed to endolaryngeal, or rather endopharyngeal, electrisation, which has been specially elaborated by von Ziemssen. You will employ for this purpose the tracheal electrode mentioned before (fig. 39, p. 487) or a double electrode devised by von Ziemssen, which allows both poles to be introduced into the pharynx. The strength of the current should be chosen so that distinct contractions or slight spasm of the frontal muscle should result from faradic or galvanic stimulation of its nerve. In unipolar stimulation the best place for the indifferent electrode is outside on the neck. The current must never be made until the electrode is fixed on the desired spot; its action can generally be kept up for a few seconds only on each spot.

The chief positions for stimulation are as follows: *Superior laryngeal nerve*; electrode in the sinus pyriformis, pressed somewhat against its anterior wall by raising the handle. *Transverse arytenoid muscle*; electrode on the posterior surface of the arytenoid cartilage. *Crico-arytenoideus lateralis*; in the depths of the sinus pyriformis, backwards and downwards. *Thyro-arytenoideus externus* and *internus*; in the same position, but downwards, inwards, and forwards. *Crico-arytenoideus posticus*; electrode from the posterior surface of the arytenoid cartilage downwards to the side of the cricoid cartilage; swallowing at the same time greatly facilitates the correct localisation. The *thyro-* and *ary-epiglottici*; directly to the sides of the base of the epiglottis. The *crico-thyroidei* can be easily stimulated through the skin.

The carrying out of this treatment presents the greatest difficulties in practice. When you hear that, according to von Ziemssen's own showing, weeks of constant practice and habit are necessary before the patients are able to bear this local electrisation at all, and the treatment itself can be entered upon; and that every such application is followed by retching, vomiting, temporary aphonia, hoarseness, pain in the throat, &c., often for many hours, you will understand that I only advise this treatment when the percutaneous application, which is much more easily carried out and almost entirely painless, has been employed thoroughly and *in vain*. According to my opinion the percutaneous application of electric currents, although it may appear less rational and direct than the endopharyngeal in many cases, is, as a rule, to be preferred to it, all the more that the therapeutical superiority of the endopharyngeal over the percutaneous application has by no means been established by experience.

It is possible that the former may deserve the preference and immediate employment in particular individual cases, especially in paralysis of the posticus. This can only be proved by further observations; but for the present I consider it to be decidedly safest and most rational to begin the treatment first with percutaneous application, and only to proceed to a trial of the endolaryngeal when this has failed.

I am the more inclined to allow an authorised position to endolaryngeal electrisation because I cannot rid myself of the conviction that it is in tracheal paralysis that a very successful field of action stands open to the reflex actions so often mentioned. The energetic physiological reflexes which are excited from the laryngeal mucous membrane, and which, of course, come into action in an increased degree by means of endolaryngeal faradisation and galvanisation, certainly play an important part in the cure of laryngeal and tracheal paralyses, and perhaps the best results of endolaryngeal irritation are to be attributed to these actions specially. But I cannot believe that an irritation strictly localised in the region of individual muscles is necessary for this end, although it is not impossible. From this point of view endolaryngeal irritation may certainly be allowed a place in therapeutics.

It is impossible to decide for certain whether the faradic moxa (energetic excitation with a firmly fixed brush), employed by Moritz Meyer with great effect in hysterical and other paralyses of the vocal cords, acts only reflexly; or because he places the brush on the skin over the trachea, so that very considerable current waves must pass into the larynx. Meyer often saw a cure even after one sitting.

As far as the therapeutic *results* in these paralyses are concerned, they are generally most striking in the so called hysterical aphonia; the voice is often restored in a few minutes, after having been lost for weeks or months; the effect, however, is not generally lasting. I treated a hysterical patient for many years, whose voice was brought back by faradisation or galvanisation every 8 or 10 days; but in other cases the cure may be lasting. The result is also generally very good in catarrhal and rheumatic paralyses and in paralysis from overexertion, especially in cases where no real paralysis is present, but only the so called atony of the vocal cord (Gerhardt.) In other cases the result depends upon the kind and the intensity of the injury which causes the paralysis.

11. PARALYSIS OF RESPIRATION. ASPHYXIA. ARTIFICIAL RESPIRATION.

For the sake of completeness I will here touch upon certain cases of paralysis of respiratory power, which depend chiefly upon want of stimulation of the respiratory centres, and which are known by the name of apparent death or asphyxia. The electric current sometimes proves of great service in such cases.

I shall not refer to the possible action of the electric current on these centres themselves—that is, directly for the asphyxia, as, for example, in chloroform poisoning. A very spirited discussion was carried on about this in France some years ago (1869) between Onimus and Legros and their antagonist Liégeois, but no solution of the question was reached.

I will rather direct attention here only to the artificial respiration set agoing by the electric current, which is calculated to preserve life until the respiratory centres can resume their independent and automatic function, and respiration becomes spontaneous. Von Ziemssen has the merit of having first practically carried out these ideas, which Hufeland, Marshall Hall, and Duchenne before him had formulated more or less clearly, and of having developed the procedure methodically, so that it is now easily and safely available to all. Still it does not appear to have come into general use, probably because the mechanical methods of artificial respiration hitherto employed, which can be carried out at once, anywhere, and without any apparatus, and which are generally sufficient for the purpose, make electrical artificial respiration appear superfluous to many. But, in any case, the procedure is easily carried out; it may be kept up for a long time—24 hours—with impunity; and it fulfils its purpose perfectly. At the same time a very efficient induction apparatus, a certain skill in the electrical stimulation of the phrenic nerves, and sufficient assistance are necessary.

In all the forms of asphyxia in which artificial respiration is indicated at all it may be carried out by *rhythmic faradisation of the phrenic and their allied nerves*, as in asphyxia from carbon fumes, from coal gas, and from chloroform or opium, in the apparent death of drunkards and frozen individuals, and in new-born children. The beneficial results collected by von Ziemssen show the efficacy of the procedure in such cases.

I have already (p. 286) described shortly the *methods* of carrying it out; I will only add that the anode should not be placed too far down on the abdomen, and that it should be chosen as large as possible, so that the inspiratory descent of the diaphragm may not be counteracted by contraction of the abdominal muscles. When you have made the application for some time, and have got the respiration in regular action, you may pause to see if spontaneous respiration has begun; if it has not the artificial respiration must be resumed, and you may keep it up in this way for several hours, even for a day and longer.

I will leave it undecided whether it might not be advisable sometimes to substitute the galvanic current for the faradic, and to attempt to increase the irritability of the respiratory centres by the occasional passage of a strong galvanic current through the cervical cord and the medulla oblongata; I have no personal experience in this matter.

12. Diphtheritic Paralysis.

In consequence of diphtheria of the throat and of other parts of the body, paralyses are often developed, which may be localised in very different parts, and which are, indeed, characterised by the peculiarity of their localisation and the significant combination of symptoms which results therefrom. These paralyses generally appear from one to several weeks after the disease has run its course, and they gradually spread, sometimes even going on to a fatal termination.

The *soft palate* and the *pharyngeal structures* are affected earliest and most certainly, their implication betraying itself by nasal speech, disturbances of deglutition, regurgitation through the nose, deficient closure of the epiglottis, anæsthesia, and want of reflex action; to these may be added paresis and paralysis of the external and internal ocular muscles (mydriasis, paralysis of accommodation, paresis of the external muscles); disturbances of the heart's action, remarkable retardation or acceleration of the pulse, weakness progressing to paralysis of the heart; paresis and paralysis of all the muscles of the trunk and of the extremities, with or without sensory disturbances, often with atrophy and various anomalies of electrical irritability, here and there even with incompetence of the sphincters; and, finally, a form of ataxia, giving a more or less complete picture of tabes dorsalis, with anæsthesia, paræsthesia, absence of the tendon reactions, &c., generally accompanied by decided and well-marked paresis, especially of the lower extremities.

A number of recent anatomical investigations have given information with regard to the manner and seat of these various paralytic phenomena; various changes, hæmorrhages, inflammations, and degenerations have been found in all possible situations, in the central as well as in the peripheral part of the nervous system after diphtheria (interstitial and parenchymatous neuritis in all the peripheral nerves and in the spinal roots, meningitic and myelitic changes, especially anterior poliomyelitis, hæmorrhages into the brain, the spinal cord, and the peripheral nerves, &c.), processes which have a favourable or unfavourable termination according to their localisation and intensity, and whose presence sufficiently explains the varied pathological appearances of diphtheritic paralysis.

The results of *electrical examination* are correspondingly varied: often the irritability of the paralysed nerves and muscles is normal; sometimes it is simply diminished; not unfrequently there is even RD. This may be demonstrated first and most commonly on the paralysed soft palate, but it may also occur in diphtheritic paralysis of the face and of the extremities. This depends, of course, upon the severity, and partly also upon the situation of the lesion.

I shall now cite a few examples (cf. also Obs. 80 and 81).

82. *Personal Observation. Diphtheritic Paralysis with Ataxia.*—A student, aged 22. Had diphtheria in August 1879; a few weeks later difficulties of deglutition, then weakness and instability of the extremities, paræsthesiæ and anæsthesia of the hands, retardation of the heart's action. Condition at the end of October 1879: Difficulty of deglutition, from paresis of the soft palate; pupils moderately dilated, with tolerably good reaction; slight insufficiency of the right internal recti; retarded heart's action, pulse 60; distinct ataxia in the arms, numbness and some amount of anæsthesia of the hands, so that he could not button his coat or distinguish the contents of his pockets; in the legs the gait somewhat uncertain, slight ataxia and decided weakness in the peroneal region, inability to stand on tiptoe; electrical irritability decidedly diminished; sensibility good in the legs, cutaneous reflexes normal, patellar reflex absent. Galvanic treatment of the sympathetic, the spinal cord, and the peripheral nerves and muscles with very good results. In the beginning of December 1879 almost cured; prolonged walking without difficulty; no more weakness in the peroneal region, patellar reflex restored, hands no longer numb, piano-playing easy again, &c.

83. *Personal Observation* (*Rumpf*). *Diphtheritic Paralysis with Ataxia.*—A girl, aged 9. Severe case of diphtheria in the beginning of October 1876. Condition at the end of October: Paresis of accommodation, insufficiency of the internal recti, pupils normal; paralysis of the soft palate, with absence of reflex; extremities still unaffected. Galvanic treatment: Transversely through the mastoid processes; and from the nape of the neck to the eyes. On November 7 insufficiency of internal recti almost gone. From that time weakness and insecurity of the legs, continually increasing ataxia of all the four extremities, with paræsthesiæ; total absence of the patellar reactions. In spite of the galvanisation of the spinal column and of the sympathetic, which

was now begun, the affection made further progress, and decided motor paresis came on, especially in the upper extremities, but also in the left facial nerve and in the legs; no objective disturbance of the cutaneous or muscular sensibility, only a diminution of the feeling of tickling. At the end of November 1876 the height of the affection was reached, and it began to improve slowly; first motility returned to the soft palate, then walking improved and the ataxia of the legs disappeared; the feeling for tickling returned later, and finally the ataxia of the hands diminished gradually. On Febuary 1, 1877, discharged almost cured; only the tendon reactions still absent, not returning till four weeks later. Complete cure.

84. *Observation by Richard Schulz. Diphtheritic Paralysis and Ataxia.*—An apprentice, aged 18. Diphtheria at Easter 1877. 14 days after recovery from that disturbance of vision, nasal speech, and difficulties of deglutition; then increasing weakness in arms and legs, numbness in the soles of the feet. In the middle of July 1877 pupils normal; vision bad, both near and distant; paresis of the right internal rectus. Speech strongly nasal, stammering. Paralysis of the soft palate. Distinct paresis of the extremities, especially of the right; cutaneous and muscular sensibility intact; distinct but slight ataxia in arms and legs. Patellar reactions absent. Large nerve trunks and the sympathetic painful on pressure. Electrical examination showed moderate diminution in various nerve trunks; no RD. Galvanic treatment: Transversely through the mastoid processes and from the nape of the neck to the eyes; current to the spine; direct treatment of the extremities and of the soft palate with the kathode labile. After 6 sittings improvement in the accommodation paresis; after 20 sittings the paralysis of the internal rectus and of the soft palate completely cured; finally, the paresis and ataxia of the extremities removed in a few more sittings. Knee jerk not yet restored on his discharge.

85. *Personal Observation. Diphtheritic Paralysis.*—A peasant girl, aged 22. Diphtheria of the fauces 7 weeks before. Soon afterwards marked weakness of the voice, gradually increasing, then difficulties of deglutition and regurgitation of fluid through the nose; for 4 weeks weakness of vision, especially near. For 8 days formication in hands and feet, without much weakness. Present condition: Nasal speech, voice very weak and somewhat hoarse, paresis of the left vocal cord; paresis of accommodation, movements of the pupil tardy; great paresis of the left half of the soft palate, less of the right, anæsthesia and want of reflex in these parts. No objective disturbance of sensibility or motility in the extremities. Electrical examination

showed marked RD in the soft palate. Galvanic treatment: Transversely through the mastoid processes, the cervical sympathetic, and the cervical cord; direct treatment of the soft palate with the kathode labile. After 4 sittings movement of the soft palate more extensive. After 10 sittings soft palate much improved, vision somewhat better. Very gradual advance of the improvement, so that the patient could not be discharged in a satisfactory condition till after 40 daily sittings. Complete cure subsequently.

The *electrical method of treatment* of diphtheritic paralysis has nothing specific about it, but must be somewhat varied on account of the diverse localisation with which you have to do. You must first of all determine, according to general rules, in what part of the nervous system the special lesion is to be looked for—in the muscles and peripheral nerves, or in the spinal roots, or in the spinal cord and brain themselves—and select the general method of application accordingly. You will then make a direct application for the ocular paralysis, the paralysis of deglutition and of the diaphragm and the extremities, in the way that I have described under its proper heading.

For the *treatment of the cardiac weakness*, which appears to proceed sometimes from the excito-motor tract and sometimes from the vagus, you may also make a trial of electricity, and you may proceed according to the recently published investigations of von Ziemssen (vide sup. p. 121), (although from the experiments of Herbst and Dixon Mann it appears to be very doubtful whether any considerable influence can be produced on the heart when the thoracic wall is intact). Von Ziemssen's method may be tried especially when the action of the heart is retarded or weakened. The method is: large electrodes, applied one on the cardiac region, the other on the dorsal vertebræ, then a current of the greatest intensity, with from seventy to eighty reversals in a minute, always taking care to begin with weak currents when the cardiac nervous system is diseased.

Further, in diphtheritic weakness of the heart galvanisation of the cervical cord and of the medulla, and stimulation of the vagi and the cervical sympathetic, may be recommended, in much the same way as I have described in the treatment of the larynx (p. 491).

The *results* of electrical treatment in diphtheritic paralysis are on the whole very favourable; but it is sometimes impossible, in spite of all pains taken, to prevent the progress of the paralysis and its fatal termination. But under any circumstances we must be prepared for a course of treatment lasting for several weeks, and often even for several months, to effect a cure of the disease.

Other forms of paralysis after acute illnesses (typhus, cholera, dysentery, acute exanthemata, especially variola, puerperal fever, intermittent fever, &c.) are to be treated according to similar rules. Here also we have to do with very varied alterations and in diverse situations, sometimes peripheral, sometimes spinal or cerebral, with severe or slight lesions, and all their consequences and symptoms. Electrical treatment must be carried out accordingly in each case with due reference to the general principles laid down elsewhere.

13. SATURNINE AND OTHER TOXIC PARALYSES.

The paralysis which occurs in consequence of chronic lead poisoning comes very often under the notice of electrotherapeutists, and is of great theoretical interest in many ways; and, as it interferes seriously with occupation, and occurs with comparatively great frequency, it is of considerable practical importance.

Paralysis is not generally one of the first manifestations of lead poisoning; it has usually been preceded by other symptoms, especially by repeated attacks of colic, and in any case the individual concerned has already lived for a long time under the deleterious influence of the lead.

Lead paralysis occurs most frequently by far in a very special and even typical form, as *paralysis of the extensors of one or both forearms*, and generally in such a way that first the extensor communis digitorum, then the extensors of the wrist, the long thumb muscles, &c., are affected, while the supinators remain free, the supinator brevis for a long time and the supinator longus generally permanently, and this is highly characteristic, and in contradistinction to most other forms of radial paralysis. The triceps too is never affected.

The development of the paralysis is generally very gradual, proceeding from one section of the extensor communis and spreading over the muscles already mentioned; very soon marked atrophy and constant RD is found, even if the peculiar development of the paralysis is carried out in a somewhat modified manner. Sensibility always remains perfectly intact. Very commonly the affection attacks both arms shortly after each other.

This is the common and very characteristic form, but occasionally other localisations occur; E. Remak has found that the frequently mentioned group of muscles (deltoid, flexors of the forearm, supinators, infraspinatus) is occasionally affected to a preponderating extent (upper arm type), so that my 'combined shoulder-arm paralysis' may also occur through lead. Not seldom we also see the lead paralysis extend itself to other muscles of the arm, and affect the median region in the small muscles of the hand, going on even to the ulnar region, the deltoid, &c., and thus it may come eventually to a *general saturnine paralysis*, in which the muscles of the trunk, the diaphragm, the lower extremities (also with typical localisation, with atrophy and RD) may be involved.

Electrical examination shows the constant occurrence of RD in lead poisoning; its advance keeps pace with that of the paralysis; when this is rapid RD becomes completely developed; if it is slow the stage of increased galvanic irritability is delayed and only the characteristic qualitative anomalies remain (tardy contraction, ACC > KCC, increased mechanical irritability). It is especially in lead paralysis that those remarkable cases have been found of isolated galvanic RD in muscles which are not paralysed at all, or which are scarcely affected in their motility (Erb, Bernhardt, Kast; cf. p. 208), irrespective of the fact that partial RD occasionally occurs here. From the long duration of lead paralysis and the frequently occurring relapses, the condition of the electrical excitability may be considerably complicated, indistinct, and confused, so that sometimes nothing definite can be evolved from the electrical examination.

RD does not always, however, affect all the paralysed muscles, but some may remain free from it, displaying either a simple and moderate diminution of electrical excitability or no anomalies at all.

This is decisive for the *prognosis*; for those muscles without RD generally return speedily to their normal condition, while those with RD generally require a very long time for their recovery. With respect to the diagnosis too a decided conclusion may be drawn from RD as to the presence of degenerative atrophy, and at the same time its presence speaks in favour of a neurotic and against a myopathic origin of the atrophy, and, with the perfectly intact sensibility, very probably in favour of a spinal origin of the paralysis, or at least an origin in the anterior roots.

At the same time, and in spite of the numerous recent investigations, the question of the essence and seat of lead paralysis is still disputed. It certainly seems to be beyond a doubt that it cannot have its seat primarily in the muscles themselves, but must be of neurotic origin; but whether the primary lesion is to be sought for in the peripheral nerves, and only in their motor fibres, or in the grey anterior columns of the cord, is not yet definitely settled. The more recent observations, which have proved a parenchymatous degeneration of the peripheral nerves, but only negative appearances in the cord, are contradicted by others which have proved positive alterations in the grey anterior columns. And although in many cases the only thing that can be definitely established is degeneration of the peripheral nerves, still I cannot regard it as certainly proved that the spinal cord is not primarily affected. What can be proved by negative results with our imperfect methods of microscopic investigation? Coarser lesions are certainly not to be expected in a toxic lesion, which generally recovers within a short time; and the *function* of the grey anterior columns and of their ganglion cells might be very considerably interfered with by the lead, without our being able to demonstrate it microscopically. And this disturbance of function is just as likely as actual disease of these tracts to cause degenerative atrophy of the peripheral nerves.

The clinical reasons, which I have already enumerated in detail ('Krankheiten der peripheren Nerven,' 2nd edit. p. 516), appear to me so weighty that at present I consider a spinal origin of lead paralysis to be more probable, but I shall accept any other pathogenesis as soon as it is conclusively proved. So far as I see none has yet been suggested, and therefore it appears to me absolutely imperative to consider the possibility of spinal localisation in the choice of treatment.

I refrain from giving any examples of saturnine paralysis; they are already sufficiently represented in literature and they are not rare in practice.

In the *electrical treatment* we must begin to work upon the seat of the lesion (subordinately, of course, to the other necessary treatment of lead intoxication). I consider it best to treat first the cervical enlargement of the cord, for two reasons—in the first place because I regard that as the most probable seat of lesion; and secondly because I assume that an electrical influence on the trophic centres here situated ought not to be without a favourable effect on the degeneration of the peripheral nerves (and muscles), even if they should be the primary seat of lesion. Apply, therefore, at first a broad ('large') electrode, covering the whole of the cervical enlargement, to the lower cervical and upper dorsal vertebræ (as much as possible to the *upper* part of the cervical enlargement, where the centres for the extensor region lie), and the other electrode on the sternum, and let first the anode and then the kathode act for one or two minutes with a strong current (10 to 25 ma., 30° to 50° N defl.), stabile. The galvanisation of the sympathetic, recommended by the elder Remak, may be added to this, although it probably acts only through the simultaneous influence on the cervical cord. You must then undertake in its whole extent, according to the customary method, the usual peripheral treatment of the extensor region (and of any other affected nerve-muscle regions), placing meanwhile the anode on the cervical enlargement. A few minutes of strong labile stimulation is sufficient for this, but when the muscular irritability is very much diminished both electrodes may be applied directly to the muscles, with reversals of the current. A possible reflex action may also be induced by this means.

The galvanic current is, of course, indicated in the first place, on account of the degenerative atrophy; but the copious experiences of Duchenne, Moritz Meyer, and others teach that the faradic current is also not without effect, perhaps chiefly in a reflex manner.

The *results* of this treatment are generally very satisfactory, but they come on very gradually, and the treatment must be continued for many weeks and months; most cases are cured, but many which are very severe and of long standing, and especially general lead paralysis, may resist all treatment and remain incurable.

Other forms of toxic paralysis will very seldom come under your treatment; they have been seen in consequence of copper, mercury, zinc, and most frequently chronic arsenic poisoning. Arsenical paralysis occurs as a more or less extensive, sometimes general paralysis of the extremities, with rapidly advancing atrophy and simple diminution of the electrical irritability, without RD (Seeligmüller). Nothing is accurately known about the primary lesion. Its electrical treatment must be carried out according to general rules.

14. MUSCULAR ATROPHIES AND HYPERTROPHIES.

It only remains for me now to say a few words about the electrical treatment of the various muscular atrophies and hypertrophies.

I have already described fully those atrophies which form part and sequence of the various central and peripheral paralyses, and their electrical treatment is to be carried out according to the general rules laid down on p. 437. This forms a part, for example, of the treatment of the forms of poliomyelitis, of amyotrophic lateral sclerosis, of progressive muscular atrophy and bulbar paralysis, of peripheral rheumatic, traumatic, and neuritic paralysis, of lead paralysis, &c.

But there are other, so to speak, idiopathic or *purely muscular atrophies*, among which I reckon the atrophy caused by want of use, by long confinement to bed and inactivity, by pressure of bandages and dressings, by anchylosis of the joints, &c.; perhaps a part of what falls under the wide designation of progressive muscular atrophy belongs to this category, especially the 'juvenile' form, and in particular the very frequent muscular atrophy which sets in in consequence of acute and chronic inflammation of the joints. Its pathogenesis is by no means explained; certainly only a very small number of cases result from a myositis following the articular inflammation; in some cases it may be a neuritis, which has led to paralysis of the muscles concerned and to consequent atrophy. But, for the most part, there is nothing of that sort to be made out, and we have only to do with a rapidly progressive simple atrophy with corresponding weakness and paresis of the muscles, which may be accounted for, perhaps, by spinal, reflex influences, proceeding from the irritation of the joint and interfering with nutrition (Valtat, Charcot); that, however, is not yet quite clear.

These muscular atrophies are especially frequent and important in affections of the shoulder and knee joints, and they affect chiefly the deltoid and the quadriceps, more rarely the peroneal region; I have also seen them several times in hip-joint affections, affecting the muscles of the hip, buttocks, and thigh. This atrophy may become very extreme, with more or less pronounced paresis, and subsequently even complete paralysis, and it is sometimes associated with pain.

It is characteristic, however, that *RD is never present* (unless we have to do with a neuritic paralysis), but that the electrical irritability shows only a simple, more or less advanced diminution, never a qualitative change. This serves as a clear indication of the identity of this atrophy in contradistinction to the neurotic, degenerative atrophies.

86. *Personal Observation. Paralysis and Atrophy of the Quadriceps in consequence of Inflammation of the Knee Joint.*—A peasant girl, aged 25. One year ago a severe and very obstinate inflammation of the knee joint; freedom from pain only for 4 weeks; since then the leg noticed to be heavy and immovable, not set down properly in walking. Present condition: Right knee joint still somewhat thickened, but free from pain; movement in it quite good. Complete paralysis of the anterior muscles of the thigh; leg cannot be raised from the perpendicular, nor the limb bent at the hip joint. Marked atrophy of the muscles. Electrical irritability simply diminished, without qualitative changes. Sciatic region unaffected. Galvanic treatment: Directly to the muscles, with reversals of the current, one

electrode in the groin. Immediately afterwards leg could be extended to an angle of 45°. Second sitting the same, but in addition currents from the spinal column to the crural nerve with reversals; after that extension to 70°. After the 4th sitting the leg could be raised almost to the horizontal position. Electrical irritability materially improved. After the 16th sitting cure almost complete. Walking still somewhat embarrassed by the swelling of the knee.

87. *Observation by Benedikt. Paralysis and Atrophy of the Quadriceps in consequence of Gonitis.*—A girl, aged 14. Inflammation of the knee joint 3 years ago, the flexure anchylosis which resulted removed by forcible extension. Total atrophy and paralysis of the quadriceps then discovered; absence of electrical irritability. Local galvanisation and faradisation; complete recovery of the muscle after several months of treatment.

88. *Observation by Le Fort (Valtat). Hydrarthros Genu Traumatica. Atrophy of the Quadriceps.*—A man, aged 35. Great swelling of the knee and difficulty in walking in consequence of a fall in March 1874. Ordinary treatment: Counter-irritation, firm bandaging, &c. The fluid disappeared, but the difficulties of walking continued. In July 1874 great atrophy of the anterior muscles of the thigh noticed; they seemed to be completely useless. Treatment: Daily faradisation of the atrophic muscles for some minutes; every night an application of a continuous galvanic current (4 elements—Morin), anode in the groin, kathode on the calf. After 14 days marked improvement; patient could walk a little. Recovery complete after a month.

The *method of treatment* of this simple atrophy is in the main the same as that of neurotic atrophy; by regular galvanic and faradic irritation of the muscles we try to improve their nutrition, to restore their volume, and to increase their power. We must be careful not to proceed, especially at the beginning, with too strong currents and too long-continued action, in order not to over-stimulate; we can gradually raise the excitation. It is also advisable to stimulate the nutrition of the muscles by excitation of the nerve trunks and perhaps also of the trophic central apparatus.

According to the views of several French authors (Le Fort, Valtat) the employment of continuous weak galvanic currents appears to be of special use in this very muscular atrophy caused by joint affections. I have already described Valtat's method (p. 285); it appears desirable to combine it with regular faradisation of the atrophic muscles.

Of course the *results* of the treatment of all these atrophies vary essentially according to their cause; you will sometimes see rapid, sometimes tardy results, but generally a consecutive and long-continued treatment is necessary.

Pseudo-hypertrophy and *true hypertrophy of the muscles* are still doubtful in their pathogenesis; the idea that they are caused by neurotic and specially by spinal disturbances has not yet been proved. You may, therefore, carry out the electrical treatment exactly according to your own discretion and your theoretical views; but I would not under any circumstances omit either an intelligent peripheral treatment or the galvanic treatment of the spinal trophic centres (galvanisation of the spine and of the sympathetic). But the results which have hitherto been obtained by the electrotherapeutics of this disease are hardly worth mentioning.

The same may be said of another rare and remarkable form of disease, specially important to military surgeons, the so called *Thomsen's disease, myotonia congenita* (Strümpell), which I have already noticed at length (p. 213), on account of its very characteristic changes of electrical irritability. It may be doubtful in what part of the system this disease is to be placed. I am inclined to include it in the general neuroses, with tetanus and the like. I have found, in excised fragments of muscle, very considerable alteration in the muscular fibres, especially enormous hypertrophy with great increase in the number of nuclei, but, as there has not yet been a thorough investigation of the motor nerves and the central nervous system, the disease may, for the present, be included here under the head of muscular diseases. There is not much to say about it from an electrotherapeutic standpoint. The attempts at electrical treatment which have hitherto been made have proved entirely ineffectual. Nevertheless, since certain anatomical changes have been demonstrated, I would encourage you still to further experiments, directed to the muscles themselves, such as general faradisation and galvanisation of the muscles, and above all faradic and galvanic baths. Central galvanic treatment must also not be neglected.

V. *PAINFUL NEURALGIC AND NEURALGIFORM AFFECTIONS.*

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LECTURE XXVI.

Introduction — Definition and Nature of Pain and Neuralgia — Neuralgic Changes — Objects of Electrotherapeutics — Removal of the Abnormal Nutritive Conditions in the Nerve and the Removal of the Causes of the Neuralgic Changes—Actions of the Current which will Effect this—Cases —Electrotherapeutic Methods—Causal Treatment—Antineuralgic Procedures: Direct—Method of the Application of the Galvanic and Faradic Current—Indirect—Electrocutaneous Brushing—Galvanic Treatment of Painful Points—General Plan of Treatment—Results.

THOSE morbid irritative processes in the sensory nerves which express themselves as hyperæsthesia and pain offer a field as wide as it is successful to the electrotherapeutist. The patients have a longing desire to be delivered from the tormenting ailment, and the physician is glad to possess a remedy like the electric current, which in very many cases removes this symptom in a surprisingly short time and with a completeness which leaves nothing to be desired.

It is especially against those forms of painful irritation of sensory nerves which have a certain individuality, which come on as special and distinctly characterised forms of disease, and which may be spoken of collectively under the name of neuralgias and neuralgiform pains, that electrotherapeutists have preferred to direct their labours; but in not a few cases the electric current has proved helpful against other painful affections also which have nothing to do with neuralgia and do not even deserve the name of symptomatic neuralgias.

The indications for the employment of electric currents against pain and neuralgia do not, perhaps, present themselves so spontaneously as in paralysis. As long as electricity was only known as a nerve excitant its employment for irritative conditions of sensory nerves did not appear very enticing. But long before the modifying, soothing actions of electric currents were known they were undoubtedly employed for pain and neuralgia (I do not know on what ground); and the indubitable and frequent results of these first experiments soon formed a wide basis for further investigations in this therapeutic domain, so that to-day we possess, in the electric current, one of the surest and most brilliant remedies for neuralgia, although we must acknowledge that we have not yet advanced very far in the knowledge and understanding of its mode of action in these forms of disease.

Here, just as in paralysis, it seems indispensable for the understanding of the electrotherapeutic actions and for the establishment of the most serviceable antineuralgic methods, first to enquire into the nature of the pain and the neuralgia, and find out what pathogenetic conditions have been at work in their production, for it is only in this way that we can really attain a rational procedure for their relief.

This certainly looks hopeless enough; in spite of the daily occurrence of these symptoms or forms of disease, in spite of thousands of years of old observations and repeated exertions, we find ourselves still in a state of very lamentable uncertainty with regard to the nature and pathogenesis of pain and especially of neuralgia. This, of course, acts as a hindrance to any rapid advance in treatment.

Pain is caused by every sensory irritative process which goes beyond a certain intensity; it is the reaction in consciousness of a certain strength of centripetal excitation. But the strength of this excitation may be produced either by the greater intensity of the actual excitation or by an increase in the irritability of the sensory apparatus, so that a small excitation may set up the pain-producing processes. But here our uncertainty begins; for it is only in the rarest cases that we know on which of these two the pain of the affection depends. Probably, however, there is generally an increased sensitiveness in pathological cases, caused by minute nutritive disturbances of the perceptive apparatus, so that the usual, slight physiological irritations, the movements of the blood and of the parts of the body, the tension of the tissues, perhaps also chemical matters in the blood and in the fluids of the tissues, are sufficient to account for the necessary strength of the exciting process. We know nothing more definite about these conjectural facts.

It is still more difficult to understand what is described as *neuralgia*, and to recognise its more intimate relations to its determining causes. Under the head of neuralgia are comprised pains of great intensity and of varied and peculiar quality, which occur spontaneously (i.e. are produced by pathological changes in the body itself), are confined to one or more special nerve regions, make themselves felt throughout their whole extent, and show decided exacerbations and remissions, even complete intermissions. These pains seem in many cases to be set up by minute, nutritive disturbances in the nerves, which have as yet baffled our histological investigations (as in idiopathic neuralgias, such as occur from cold, malaria, poisons of all sorts, anæmia, hysteria, neurasthenia, spinal irritation), while they are also, in a great number of cases, the consequence or even the accompaniment of grosser anatomical changes in the different parts of the sensory apparatus (traumata, foreign bodies, compression, inflammation and degeneration in the peripheral nerves, neuroma, diseases of the spinal cord, tabes, probably also diseases of the brain, syphilis, &c.) Closer observation shows, however, that the manner in which the neuralgic pains are set up by all these agents is by no means a direct influence, but that the neuralgia is something quite different from the sensory excitation set up by its cause; and we are therefore driven to the hypothesis that through the action of these causes another process must be developed in the nerve, which gives origin to the neuralgia. We have therefore come to the entirely hypothetical conclusion that *neuralgia constitutes a special and peculiar form of nutritive disturbance in* *the sensory nerve apparatus*, for which Möbius has employed the name of 'neuralgic change.' This peculiar alteration in the nerve first constitutes the neuralgia. So long as it persists the neuralgia persists also; if the causes of it continue the 'neuralgic change' must gain ground, or after a temporary abatement may be set up again. This alteration sometimes attains a certain independence and may then persist after its cause has ceased (habitual neuralgia). Moreover it may apparently establish itself in various parts of the sensory fibres, in the peripheral as well as in the central tracts; at all events there is nothing to prove that it is always found in a certain spot (e.g. in the posterior spinal roots or in the ganglion cells of the grey posterior columns, as many authors will have it). We are quite ignorant of what constitutes this 'neuralgic change,' but it is very unlikely that hyperæmia or a slight neuritis is always and under all circumstances at the bottom of the alteration.

It is not my task here to enter more particularly into the symptomatology of neuralgias; I will only point out briefly that it is of importance for electrotherapeutists to inform themselves accurately as to the nerve trunk the neuralgia affects, if possible also as to its exact position in the distribution of fibres, and as to the probable grosser causes. They must diligently search for the presence of Valleix's pressure points. In many cases it is also advisable to search for other pressure points, especially in the neighbourhood of the spinal column (apophysis points of Trousseau).

Electrical examination has not as yet acquired any importance in neuralgia, nor has it been conducive to the recognition of the finer molecular changes in the sensory nerves, perhaps because it has not been yet pushed far enough. The insufficient investigation of the sensory trunks generally (p. 225 et seq.) makes itself felt in this department, and for a long time nothing has been accurately known of the changes in the law of sensory reaction or of any increase and diminution of the electric irritability in neuralgic nerve trunks. All that has as yet been found out by electrical examination is limited to certain questions which can be settled by other methods of investigation, such as the demonstration of hyperæsthesia or anæsthesia in the neuralgic cutaneous region, of painful points in the nerve trunk or its branches, or, finally, of galvanic painful points in the vertebral column (Moritz Meyer, Brenner), things which are not exactly unimportant, but which are of very little service for the pathology of neuralgias.

According to these introductory considerations, then, the first electrotherapeutic task with respect to neuralgias is the *removal of the abnormal nutritive and irritative conditions in the nerve*—the removal of the 'neuralgic change.' But even when this is effected—and the electric current appears to accomplish it with some degree of certainty in many cases—it will not in all cases suffice for the permanent cure of the neuralgia; if its causes continue the neuralgia will always return. We have, therefore, a second and often a much more important and difficult task—that is, *the removal of the causes of the neuralgic change.*

After what we have had the occasion of repeating more than once you will have no doubt as to the fact that the electric current can easily fulfil both these tasks under suitable circumstances; and I may, therefore, confine myself to a short indication of those actions of the current from which we may expect, with more or less reason, a favourable influence on the neuralgia.

As the clinical symptoms compel us to assume that the changes in the nutrition and in the molecular relations of the neuralgic nerves is very slight—for there can be no serious nutritive disturbances in a nerve whose function is perfectly normal between the paroxysms of pain—and as we must consider these changes as being in most cases accompanied by an increase of the irritability, the *modifying action* of the electric current is to be first resorted to; by which is meant the diminution of the irritability, the production of anelectrotonus, the so called soothing (antineuralgic) action.

In the same direction, however, for the removal of more minute nutritive disturbances the *katalytic actions* in the wider sense of the word may be employed; and these have a decided influence also in a whole series of causes of neuralgia —hyperæmia, neuritis, degeneration, and various diseases of the brain and spinal cord. Hence in neuralgia also the most extensive field is probably occupied by these katalytic actions.

Finally, the *stimulating actions* may also be resorted to, and in such a way as to produce very strong sensory excitation, which, as the so called counter-irritation, is very extensively employed in neuralgias and other painful affections. However vague this conception may be it still remains firmly settled by experience that abnormal sensory irritative conditions may be relieved, temporarily or permanently, by strong sensory excitation either in the same or in symmetrical or distant nerve tracts, whether it be by molecular inversion, by over-stimulation and exhaustion, or by central limitation (perhaps by means of reflex circulatory changes and the like). We do not yet know anything more certain concerning it; but in any case the electric current is one of the surest and most energetic, as well as a perfectly harmless means of producing a strong counter-irritation.

Whether these are the only actions of the current which are useful for neuralgia or not, whether or not other influences, as yet unknown to us, may also play their part, so much is certain, that literature, as well as the personal experience of every electrotherapeutist, furnishes numerous examples of the excellent results of this treatment in neuralgia, though of course accompanied by a certain number of failures. I will cite briefly a few examples, in order to show you the different methods of attaining good results.

89. *Observation by Weise (Hitzig). Neuralgia Supraorbitalis Dextra Typica.*—At the end of December 1866, following a common cold, an attack of supraorbital neuralgia, which took on a typical character and returned in daily, very violent paroxysms of pain, ending with perspiration. Quinine and arsenic useless. On January 17, 1867, galvanic treatment: A on the supraorbital foramen, K on the neck, stabile, 8 elements, for 3 minutes. Considerable relief at once; permanent disappearance of the neuralgia after the termination of the sitting. Twelve years later another attack of the same neuralgia, also uninfluenced by quinine, and also again cured by a single application of A stabile.

90. *Personal Observation. Neuralgia Supraorbitalis Dextra Typica.*—A carter, aged 50. Ill for 14 days. Characteristic localisation in the supraorbitalis; no cold, no history of malaria. Severe pain from 8 in the morning till 5 in the afternoon, then an intermission and quiet all night. Great tenderness on pressure. February 17,

1882. Galvanic treatment with A stabile; 3 days free from attacks. On February 20 pains again, second application; pain again disappeared, only returning in slight twinges. Permanent cure from 2 more sittings.

91. *Personal Observation. Neuralgia of Third Branch of Right Trigeminus.*—A woman, aged 40. Had a similar affection on the left side 10 years ago, which lasted for one year. For 2 months pain in the region of the right inframaxillary and auriculo-temporal nerves, coming on with great severity especially towards evening and in the night. Tenderness on pressure on the mental foramen and in front of the ear. February 16, 1866. Galvanic treatment, descending current stabile through the auriculo-temporal nerve and along the lower jaw for 2 or 3 minutes in each case. During the night following no pain for the first time for many weeks. Five more similar applications resulted in permanent cure.

92. *Personal Observation. Neuralgia Nervi Trigemini Dextri* (*Tic Douloureux*).—A peasant woman, aged 47. Suffered for 4 years from an increasingly severe neuralgia of the face, principally confined to the infraorbital nerve, affecting the cheek bone, the upper jaw, the nose, and the upper teeth, but during the height of the paroxysms spreading also to the lower jaw and the under teeth. Severe convulsive twitching of the angle of the mouth with each attack. Very typical case, without any other symptoms at all. Cause unknown; no distinct pain on pressure. Galvanic treatment: A stabile to the upper and lower jaw and in front of the ear for 3 or 4 minutes, the current being increased and diminished; after 5 sittings no sign of improvement. Then 8 elements from the forehead to the nape of the neck, stabile, galvanisation of the sympathetic, and A stabile in front of the ear; no improvement after 3 sittings. Thereupon faradisation transversely through the head, K on the right, with increasing currents. Improvement set in immediately, making great progress in the next 14 days; complete rest during the night, disappearance of the reflex twitchings, and only rare and slight paroxysms during the day. Treatment obliged to be broken off.

93. *Observation by Moritz Meyer. Neuralgia Nervi Trigemini.*—A lady, aged 35. Suffered for about 3 months from severe neuralgia of the left trigeminus, principally in the third division, severe attacks five or six times a day. Quinine, arsenic, veratria ointment useless. Faradic brushing of the nape of the neck (with the electric moxa) caused first a considerable increase of the pain for half a day, but afterwards surprising relief. Permanent recovery after 2 further applications.

94. *Observation by Wiesner. Neuralgia Nervi Trigemini (Tic Douloureux).*—A forester, aged 64. Suffered for 4 years from left trigeminus neuralgia (cheek bone and depths of the skull); various operations brought only temporary relief; attacks at last of frightful severity 20 or 30 times a day; 5 decigrammes ($7\frac{1}{2}$ grs.) of morphia taken daily. Galvanic treatment, the specially painful spots being placed between the sponge electrodes, twice a day for 5 minutes. Improvement after 2 days; progress slow. After 2 months no more attacks; patient discharged as cured for the present.

95. *Observation by Moritz Meyer. Neuralgia Occipitalis Dextra.*—An officer, aged 32, suffering for 2 months (as several times before) from severe pains in the right occiput and nape of the neck, showing themselves to be occasioned by occipital neuralgia. Energetic faradic brushing to the neck; immediate cessation of pain; complete recovery after 2 more sittings.

96. *Personal Observation. Neuralgia of Median Nerve.*—A woman, aged 28, suffering for 6 weeks from severe neuralgic weakness in the region of the right median nerve, from the elbow to the fingers. Nocturnal exacerbation of the pain. Galvanic treatment, descending stabile through the median nerve for 3 or 4 minutes. Much less pain during the following night. Cure after the second application.

97. *Personal Observation. Neuralgia of Musculo-Spiral.*—A girl, aged 8. Had suffered for 9 weeks from severe pain and great hyperæsthesia of the right thumb, the pain extending along the radial margin of the thumb and forearm over the external surface of the elbow up to the shoulder; pain on pressure very distinct in several places. The thumb itself acutely painful on the slightest touch; complete inability to use the hand; no swelling, inflammation, or the like. Galvanic treatment: 8 to 12 elements descending and stabile from the radial nerve in the upper arm to the thumb and wrist, 8 elements with A stabile on the plexus. After 2 sittings decided improvement; after 7 sittings complete cure; tenderness of the thumb completely disappeared, hand again useful.

98. *Observation by Seeligmüller. Neuralgia of Left Musculo-Cutaneous Nerve.*—A woman, aged 43. Suffering for 8 years with neuralgic weakness in the left arm, occurring with greater or less intensity. Examination showed that it depended on neuralgia, confined to the musculo-cutaneous nerve of the arm. Tenderness on pressure near the spinal column. Galvanic treatment: K on the tender spots, A on the nerve in the upper arm, stabile for 6 or 10 minutes, the current being increased and diminished. After the first sitting 24 hours' freedom from pain for the first time for 8 years.

After a few more sittings, interrupted for a few weeks by an attack of facial erysipelas, patient could go home cured.

99. *Personal Observation. Intercostal Neuralgia. Herpes Zoster.*—A girl aged 15. Zoster intercostalis for 4 days, corresponding to the intercostal nerves from the fourth to the seventh, from the back to the mamma, and on the extensor surface of the upper arm, with neuralgic pains in the same region. These pains continued 14 days, in spite of indifferent treatment at first, afterwards morphia. Galvanic treatment; pains completely cured in 5 days. Treatment discontinued; pains returned in 5 days. Galvanic treatment resumed, resulting in cure after 10 days.

100. *Personal Observation. Intercostal Neuralgia. Mastodynia.*—A servant girl, aged 26, suffering for about 8 or 9 months from stabbing pains in the breasts, accompanied by secretion of milk. Pains sometimes very severe, with strong remissions, coming on in frequent attacks, radiating to the back and the internal surface of the upper arm. Tenderness in most of the dorsal spinous processes. Anæmia. Galvanic treatment: A on the dorsal vertebræ, K on the sternum, 14 to 20 elements, stabile, diminishing gradually to nothing. After a few days decided improvement, but no further progress. Thereupon faradic treatment (strong currents with large moist electrodes) was instituted; decided improvement, the affection being reduced to two mild attacks in the day. Complete cure not attained.

101. *Personal Observation. Sciatic Neuralgia.*—A man, aged 23. Neuralgic pains for 5 days, from chill, in both legs, from the hips to the feet. Exacerbations during the night, preventing sleep. Paræsthesiæ of the feet. Galvanic treatment: Descending by 6 inches at a time along the course of the sciatic nerves, with some interruptions. Pain less, sleep good, and leg tolerably free from pain. After the second application no pain at night. Cure after the fourth application.

102. *Personal Observation. Sciatic Neuralgia.*—A man, aged 55. Suffering for 3 months from left sciatica. Characteristic localisation of the pain, with tender points on pressure; severe paroxysms, especially in the night; sleep much disturbed; left leg somewhat emaciated, walking much embarrassed. Subcutaneous injections of morphia useless. Galvanic treatment: Descending stabile through the nerves, finishing up with some interruptions of the current. Considerable improvement even after the first application, which progressed from day to day, so that patient was discharged cured after 9 sittings.

103. *Observation by Moritz Meyer. Sciatic Neuralgia.*—A merchant, aged 44. Suffering for 6 months from right sciatica, in consequence of a railway accident. Very severe pain. Spot over the sciatic foramen painful on pressure. Faradic brushing in this region; immediate disappearance of the pain, which returned slightly on the following day. Cured after 2 more sittings.

104. *Observation by Brenner. Sciatic Neuralgia.*—The patient, a steward, suffered for 4 months from excessively severe sciatica, obliging him at first to remain in bed for a month. Peripheral electric treatment relieved the pains in the lower part of the leg, but not in the upper part of the sciatic nerve nor in the ilio-hypogastric nerve. Examination showed intolerable pain on being touched with the kathode in the lumbar and sacral vertebræ, which were not painful on pressure. Treatment with the anode on these situations was followed by immediate relief, and after 8 further applications the patient was nearly free from neuralgic pains, the galvanic painful points having disappeared.

105. *Self-Observation by Brenner. Neuralgic Pains in the Foot, in consequence of Articular Rheumatism.*—In consequence of acute rheumatic polyarthritis, affecting both ankle joints, Brenner suffered from severe paroxysmal pains, radiating into the feet, which resisted all remedies and made sleep almost impossible for 3 weeks. A single application of a moderately strong faradic current, conducted through the ankles by means of broad, moist electrodes, relieved the raging pain at once and permanently.

Compare also Obs. 25, 26, 29, and 31 (neuralgias in tabes); Obs. 44, 46, and 48 (neuralgias of the trigeminus and occipital); Obs. 36, 42, 43, and 47 (neuralgias of the upper extremity), and Obs. 45 (sciatica).

From these observations it may be gathered with certainty that many neuralgias are cured in a surprisingly rapid manner by means of the electric current, and that this is possible with very various methods; but a superiority of one method of application over another is by no means to be inferred from them, and is certainly not to be deduced from the assertions of those who have cultivated the one or the other method more or less exclusively. In some cases it appears, indeed, as if, when one method has failed, another might be successful; but that is by no means frequent, and I have very often received the impression that those forms of disease which yield to the electric treatment at all are beneficially influenced by every kind of current and by every method of application which is not entirely irrational.

In determining the electrotherapeutic methods for neuralgia you have to regard the *removal of the causal affection* as the first duty in many cases. On this point I have hardly anything to add here to what I have said in former lectures (Lectures XVI. to XXI.) In the first place we have to do with the electric treatment of those diseases of the brain, the spinal cord, and the peripheral nerves, which occasion the neuralgias or the neuralgiform pains. This is carried out exactly according to the rules and methods which have already been given you, and it is what has first to be attended to in the so called symptomatic neuralgias (in tabes, meningitis, neuritis, &c.) As a rule we shall have to have recourse to a suitable employment of the galvanic currents, or more rarely to make use of the faradic current for its reflex action on the skin.

But, as not a few neuralgias develope on the soil of general neuroses (hysteria, neurasthenia, spinal irritation, diabetes, &c.), or on that of general constitutional anomalies (anæmia, chlorosis, cachexiæ of all kinds, &c.), electrical treatment—not to speak of other remedies, which are not to be considered here—may occasionally be of service in these diseases also, and here the 'general faradisation,' which was much recommended by Beard and Rockwell for this kind of neuralgia, as well as the 'general' and 'central galvanisation,' may be employed. Neftel specially recommends galvanisation of the brain and in many cases very energetic galvanisation of the cervical sympathetic. I will return to this in subsequent lectures.

But the principal thing which has to be done under all circumstances in idiopathic and symptomatic neuralgias, and which may be tried even in incurable affections and be of use as a palliative in them, is the *removal of the diseased condition in the sensory nerve itself*—the removal of the 'neuralgic change,' i.e. the attainment of the soothing, antineuralgic action of the electric current. This may be done either directly or indirectly.

The first, the *direct* way, naturally lies nearest; we take it first, therefore, as a rule, and we may make use either of the galvanic or of the faradic current. The aim must always be to diminish the irritability, and to act in a modifying manner on the nutritive relations of the sensory nerves, in a certain sense in a katalytic manner. For this purpose *the stabile action of the galvanic current* is to be tried before everything else, and you will first employ the stabile action of the anode on the diseased part, on account of its notoriously soothing anelectrotonic action. The anode is to be applied to the diseased spot itself, or at all events as extensively as possible to the painful nerve trunk, and subsequently to the several painful and tender points. Von Ziemssen recommends for this very large plates (' giant electrodes '), which should, wherever possible, cover the entire region of the diseased nerve. A moderately strong application, gradually increasing in intensity and somewhat prolonged, should properly be made ; all stronger excitation, and especially every interruption of the current, is to be carefully avoided, and in many cases it is necessary for the result to remove the current gradually at the end of the period of the anode, in order to prevent the shock of opening and the consequent positive modification of the irritability. This is easily managed by the slow diminution of the number of elements or by means of a suitable rheostat. The position of the kathode may be an entirely indifferent one, and it is in any case so to be chosen that the anode, according to the laws of current diffusion, may have as intense and widespread an influence as possible. The kathode may also be applied at the same time to the special painful points, or, according to Neftel, in many cases (especially in hysterical neuralgia) to the part on the other side of the body symmetrical to that occupied by the anode (symmetrical polar method). This procedure does not always lead to the desired result, and then an attempt with the *stabile action of the kathode* is by no means excluded. It is possible indeed that the katalytic action of this pole may have a more favourable influence on the ' neuralgic change ' and so act curatively; in any case manifold experience teaches that the influence of the kathode on the painful spots may have a beneficial antineuralgic effect (even if the anode is not placed directly on the nerve trunk). I have myself seen the lancinating pains of tabes, especially if they were associated with circumscript hyperæsthesia of the skin, disappear in a magical manner by the application of the kathode on these cutaneous spots, the anode being on the spinal column.[1]

As we have frequently to influence great tracts of nerve—as, for example, the nerves of the extremities—we may apply both poles to the nerve and allow the current to pass either in an ascending or a descending direction; the descending current is generally preferred for this purpose, and is considered to have a greater 'soothing' influence, whether justly or not it is hardly possible to say. Probably it depends on the fact that the anode is placed upon the central portion of the nerve; the *stabile* application is here again indicated, together with the prevention of unnecessary irritation. The anode will be placed as centrally as possible on the nerve trunk, or on the spine, and the kathode on a more peripheral position, especially on the several painful spots. In very long nerves, such as the sciatic, a succession of several of such applications may be made, one after the other, from the centre towards the periphery, the electrode being about 20 to 25 centimetres apart. In the case of neuralgias of mixed nerves, with stiffness, weakness, and pain on movement, it may be useful, according to Remak's custom, to excite muscular contractions by means of a few closures of the current at the end of the sitting; this generally removes these complications.

Another method which works in the same direction is the *continuous action of weak galvanic currents* (vide p. 284), which has been recommended on many sides. I have not much personal experience of it, but I believe the procedure to be worthy of occasional trial, especially for very irritable individuals with fugitive or frequently recurring neuralgias, particularly, therefore, in spinal irritation and hysteria. In the choice of the site of application it must not be forgotten that in the simple galvanic elements the zinc plate is the anode.

The *passage of a moderately strong faradic current through the diseased nerve* (by means of moist electrodes) serves the same purpose; it is difficult to say how this acts, but the fact of its efficacy is indubitable. It is best to begin at first with moderately strong currents, which will be passed through the nerves in a regular manner for from 3 to 10 minutes; this causes great relief at first and cure on frequent repetition. If this fails a stronger current is to be employed, and if necessary the so called 'swelling' current.

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[1] Neftel has successfully treated very obstinate neuralgias with stationary painful spots (neuroma?) by means of electrolytic action (K needle on the painful spot).

Results may be attained in neuralgia *indirectly* also in a number of different ways, and first by setting up a *severe counter-irritation by means of the faradic brush.* This method, specially developed by Duchenne and Moritz Meyer, and often employed with brilliant results, although not very agreeable to the patients on account of its pain, consists in stimulating the skin very energetically by means of the electric brush (faradic or galvanic). According to Duchenne the skin in the neighbourhood of the painful spot, or beyond it if this be not sufficiently sensitive, should at the same time be brushed in the usual manner; but Meyer has seen this method answer only if anæsthesia of the skin exists simultaneously with the neuralgia, and he has found it to be still more efficacious to employ the so called *electric moxa* (fixing of the faradic brush on a particular part of the skin, or, still more intense, the passage of sparks from the brush held one millimetre away from the skin) on the most painful spot in the nerve, or over its point of exit from the central organ; this application lasts from a few seconds to one minute. If this does not lead to the desired result soon (after 2 to 5 sittings) we may try the application of this powerful counter-irritation to symmetrical points on the sound side of the body, or in the region of neighbouring cutaneous nerves, or even on distant parts of the skin (the great toe, nostrils, nipples, neck, &c.) But a very strong and very painful stimulation is always necessary for this.

A case communicated by Wiesner shows that the *galvanic brush* (K), which is perhaps still more painful, is also useful in the same way. An older colleague of my acquaintance cured a very severe supraorbitral neuralgia of many years' standing by the application of the galvanic brush to the forehead, but he modified somewhat the disagreeableness of the procedure by the interposition of moist blotting-paper. Seeger employed a similar method in sciatica. He touched large surfaces of skin over the diseased nerve with the kathodic brush until redness and wheals were produced, and then made use of these places, which were rendered more accessible to the current, to lay moist blotting-paper over them and pass the current through them by means of ordinary electrodes.

The *galvanic treatment of painful spots* on the spine and the like may be regarded as an indirect treatment of neuralgia. Moritz Meyer, Seeger, and Brenner have directed their attention to this, and have found it very useful in many severe neuralgias (brachial and intercostal neuralgias, sciatica, &c.) The method consists in the stabile action of the anode of a moderately strong current.

General rules, and more especially, of course, the peculiarities of the special case, must determine the intensity and duration of all these different methods of treatment. It is advisable, under all circumstances, to begin with weak currents and short sittings, to avoid all unnecessary irritation, sudden closing and opening of the current, and the like, and to increase the intensity and duration and remove the current very gradually. More than 3 to 5 minutes of a galvanic and 5 to 10 minutes of a faradic action is hardly necessary; sometimes several sittings on the same day prove useful. Von Ziemssen recommends the current to be applied as often as there is an exacerbation of pain, which must of course be attended to by the patient at home.

With regard to the general plan of treatment, it is better to begin at first with the milder procedures, especially if we have to do with unknown and perhaps very sensitive individuals. At first, then, besides the causal treatment which may be necessary, let us employ the stabile action of the anode, or weak descending galvanic currents, and subsequently weak faradic currents, which, in particularly sensitive individuals, may be applied by means of the 'electric hand.' Only when these are ineffectual should we employ stronger currents, the faradic brush, or the moxa.

The *results* of these different kinds of treatment are frequently very brilliant, and we may say in general that neuralgias of the most varying kinds and in every situation are among the most gratifying subjects for electrotherapeutics. In almost every case a momentary result at least will be obtained; the patients experience relief during the passage of the current, and after the conclusion of the application the pain has either entirely disappeared or is considerably lessened. But that is not always the case, for there are forms in which not even a momentary relief is obtained, the pains continuing to rage with unabated violence and even increasing with the application of the current; it is seldom that such an increase of the affection is followed by a lasting relief (Obs. 93). In such cases, therefore, the treatment need not be continued for long.

In favourable cases this momentary improvement may continue, the disease being cured by one or two applications; or the pain may return again after a shorter or longer period, even if with diminished intensity, each sitting causing an improvement, until at last, sooner or later, sometimes after a few, sometimes only after many sittings, a cure is effected; in such cases you must not let yourself be discouraged by the trouble of a long-continued or a frequently repeated treatment. In unfavourable cases, however, we have only momentary improvement; the patient makes no real advance, and the neuralgia remains uncured. The reason of this generally lies in the nature and incurability of the fundamental lesion itself; but we are not always in a position to diagnose this correctly, and apparently favourable idiopathic neuralgias may present unexpected resistance to the electric treatment.

It is not easy to say beforehand whether a neuralgia is curable by electricity or whether it can with certainty be cured at all. With regard to this our diagnosis is often much too uncertain; but experience teaches that relatively favourable prospects are present in purely idiopathic neuralgias, in the rheumatic and neuritic forms, in those caused by anæmia, neurasthenia, and hysteria, and perhaps also in many organic neuralgias. The neuralgias which are mostly symptomatic, on the contrary, are unfavourable, and yield at most only palliative results, as, for example, in cerebral and spinal affections, in severe peripheral nerve lesions, in very long-standing hysteria and neurasthenia, and especially in the severe facial neuralgias which are regarded as true *tic douloureux*. In such cases you may certainly make a trial with the electrical current, but you must not promise either yourself or the patients too much from its application.

LECTURE XXVII.

Various Forms of Neuralgia—1, Neuralgia of the Trigeminus — Practical Remarks on the Various Methods of Treatment — 2, Cervico-occipital Neuralgia—3, Cephalalgia and Migraine—Different Methods of Treatment—4, Cervico-brachial Neuralgia—5, Intercostal Neuralgia—6, Neuralgia of the Lumbar Plexus—7, Sciatica—Various Methods of Galvanic and Faradic Treatment—Neuralgia of the Urinary and Genital Organs —Coccygodynia — 8, Neuralgia of the Joints — 9, Visceral Neuralgia — Neuralgia of the Fauces and Larynx — Angina Pectoris — Gastralgia —Enteralgia — Lead Colic — Neuralgia in the Region of the Pelvic Nerves.

After the full details which have already been given of the electrotherapeutics of neuralgias in general I may pass at once to the description of the individual forms, confining myself in each case to a few remarks of a practical nature.

1. *Neuralgia of the trigeminus and its branches* presents very considerable difficulties to electrical treatment, on account of the deep position of the nerve and its branches, and frequently too on account of the severity and incurability of the affection (diseases at the base of the skull, aneurism of the carotid). A little consideration shows that it is by no means easy to reach by means of the electric current the trunk of the nerve (lying deep down in the middle cranial fossa), the Gasserian ganglion, and the three main divisions, and the same holds good for part of the course of the deep branches and for those along the floor of the orbit and in the pterygo-palatine fossa. It will not be easy here to develope an energetic polar action, and still less need we expect a definite and effectual passage of the current into the nerve. In order to attain polar action it will be most effectual to pass the current transversely or obliquely from the middle of the temporal region, immediately above the zygomatic arch, to the opposite side, or behind the ear and towards the opposite side of the nape of the neck; but, in order to attain a particular direction in the

principal trunks, the passage of the current from the nape of the neck to the different points of exit on the face will hardly be sufficient. We must help ourselves as well as we can in this matter, and I believe it is best, keeping this aim always before our eyes, to bring the presumably diseased section of the nerve into the region of the densest current waves—that is, exactly between the electrodes, or as near as possible to one of them. In this respect some of the peripheral branches of the trigeminus, especially the supra-orbital, the auriculo-temporal, and the inferior maxillary, are much more favourably placed than others, and they may be easily and accurately reached by polar actions, as well as traversed by a descending current. This is least easy in the case of the infra-orbital, of which only the very terminal twigs can be energetically acted upon, and, as we know, this nerve is the favourite seat of the severe 'epileptiform' neuralgia, the true *tic douloureux.*

You will find it best to begin the treatment of these neuralgias with the stabile action of the anode on the various branches and points of exit in the neighbourhood of the main trunk, if possible. The kathode may be placed on the sternum or on the hand of the opposite side, or perhaps on the nape of the neck, posteriorly or laterally. The current must be gradually increased and diminished, its strength being moderate at first, afterwards greater, and if you suspect the seat of lesion to be at the base of the skull you must pass on to tolerably strong currents. O. Berger got very good results from this method, and it is sufficient for most of the less severe cases. If it is not effectual you may try, while the anode remains on the nape of the neck, to treat the several points of exit with the kathode, stabile (the so called descending current of some writers), or to send a descending current through the different peripheral twigs, which is possible in some of the above-mentioned instances, or you may make the same application with weak, gradually increasing, or 'swelling' faradic currents, for which Bruzelius recommends very long sittings (10 to 30 minutes). Finally, there still remains to be tried the faradic brush, the faradic moxa, and, if necessary, also the galvanic brush. This, indeed, can hardly be employed for the face, although I have tried it repeatedly; and it is, therefore, better to try brushing the nape of the neck. Moritz Meyer takes two brushes for this purpose, one of which is placed firmly on the neck, whilst the other is held about 1 millimetre from the skin in the immediate neighbourhood, so that sparks may pass from it to the skin. Faradic brushing of the helix may also be resorted to for this purpose.

But you will often meet with cases in which all these methods of treatment fail, and the true *tics* especially will drive the physician to despair, for permanent results are very rare in these cases. I acknowledge frankly that I cannot myself boast of one single brilliant and lasting cure in these severe, long-standing neuralgias, although I have treated them methodically and perseveringly. The best that I have been able to attain to has been temporary cessation of the attacks or varying degrees of relief, although here and there a cure may perhaps result. In such cases I will leave it to your own sagacity, after you have tried all the methods mentioned, to find out new ones and to discover new points of departure. I will only remind you that you have your choice between treatment of the brain longitudinally and transversely, treatment of the sympathetic, central galvanisation, general faradisation, treatment of points painful on pressure, and the employment of weak continuous currents. I will also remark that, in many cases, two or more sittings in one day appear to me to be useful.

2. The electrical treatment of *cervico-occipital neuralgia* does not present the slightest difficulty, as we have to do with superficial, tolerably long nerve trunks, which are easily reached up to their entrance into the central organ, and whose most frequently diseased portions are generally easy to hit upon. The methods may be very simply defined: in the first place the anode stabile on the points of exit—namely, the upper cervical vertebræ—the kathode being on the sternum; or a descending stabile current, the kathode being placed on the well-moistened vertex; the employment of the faradic current in the same way with moist electrodes; and, finally, the faradic brush or the moxa high up in the nape of the neck. The results are generally excellent, although here also there are cases

which defy all treatment. The rare *neuralgia phrenica* may be treated according to exactly the same rules.

3. I must devote a little consideration to the electrical treatment of *cephalalgia* and *migraine*, as it is sometimes of great service to the patients.

I refer, of course, only to the so called 'nervous' cephalalgia, occurring under the most varying circumstances, with or without grosser lesions on or in the skull, in neurasthenic, hysterical, and anæmic patients, or as rheumatic, toxic cephalalgia, &c.; other forms (occurring in fever, syphilis, inflammation of the cranial structures, catarrh, meningitis, &c.) will hardly ever be made the subjects of electrotherapeutic experiments.

It is unnecessary to say that in all such cases the discovery of the cause of the nervous pain will be our guide to the treatment, and some other treatment than the electric will often fulfil the causal indications better. In neurasthenia, hysteria, and the like, however, the causal indication may be sometimes fulfilled by 'general faradisation' or other electrical procedures. But besides this, and in all cases in which no causal indication is to be found or fulfilled, you may try the direct treatment of the headache. This may be done in various ways, which have still to be accurately determined. When the pain is more *diffused* (pressure in the head) you had better begin with the passage of weak galvanic currents longitudinally through the skull. If distinct vasomotor disturbances are present you may, according to circumstances, place either the anode or the kathode on the forehead, founding your choice on Löwenfeld's discoveries, or galvanisation of the sympathetic or of the cervical cord may be tried. The stabile action of the anode (large head electrode) on the skull is also often effectual, the kathode being placed on the sternum, thigh, or hand, with a moderately strong current, which may be gradually, perhaps, increased or diminished. I have often seen very good results from the passage of a weak faradic current from the forehead to the nape of the neck, preferably by means of the 'electric hand,' for 2 to 5 minutes; and faradic brushing of the skin of the neck, the chest, the back, and upper extremities (according to Rumpf; vide p. 264) may also be useful in some cases, especially if vasomotor disturbances are present. If the pain in the head is more *local*, with separate painful spots and the like, the stabile anodic treatment of the spots, or their faradisation with moist electrodes, will prove very helpful. The *results* of all these experiments are not to be depended on, electricity, like other remedies, having sometimes very brilliant, sometimes entirely negative results in these obscure and unintelligible forms of disease.

That form of nervous headache which occurs in periodical, typical attacks of generally one-sided and very severe pain combined with nausea, vomiting, general prostration, various vasomotor disturbances, &c., which is known as *hemicrania* or *migraine*, and from which innumerable 'nervous' individuals suffer, has, of course, again and again led to electrotherapeutic investigations. I must say that these experiments have generally been sadly ineffectual. The apparently brilliant results which individual authors (e.g. Frommhold) claim to have obtained have not been confirmed by others, and this fact separates migraine from the other neuralgias, with regard to which electrotherapeutics boasts of its greatest triumphs.

Migraine is, in the majority of cases, the expression of a congenital or acquired nervous disposition, and rarely the consequence of temporary and occasional injuries. That which on small provocation occasions the migraine, or increases the severity and frequency of the attacks, in nervously disposed individuals may also produce the affection for some length of time in people who are less disposed to it; but in such cases the attacks are generally isolated and not very severe. It is the latter that present by far the most favourable chances for electrical treatment, and I have often seen such cases recover very quickly. On the other hand the true, regular migraine, occurring in so many neuropathically afflicted women and in neurasthenic men, especially in brain-workers, and generally continuing into advanced life, is an affection which it is very difficult to influence, and which can very seldom be reduced even by the most careful electrical treatment. A real cure is hardly ever accomplished, and even considerable relief is very rare. In this respect my own experiences agree entirely with those of O. Berger, although I cannot fully agree with the view expressed by that author as to the absolute uselessness of every kind of electrical treatment.

The real nature of migraine is still entirely unknown to us, and therein consists part of the difficulty of its treatment, as we neither know in what part of the cranium or the cranial contents the pain has its seat nor what is its exact pathogenesis. I consider that the attempt to refer the pain to vasomotor disturbances—spasm or paralysis of the vessels—and to seek the nature of migraine in a disease of the sympathetic has failed; for in by far the greater number of cases which I have had the opportunity of observing the oft-mentioned angiospastic and angioparalytic symptoms have been entirely wanting during the attack. Even where they are present I can only regard them as the consequent or accompanying symptoms of the whole seizure, whose essential nature still appears to me perfectly obscure.

Electric treatment, therefore, must be limited in migraine almost entirely to an empirical experiment, and we shall find clearer indications for the choice of methods only where decided vasomotor disturbances—symptoms of irritation or paralysis of the cervical sympathetic—are present.

Of course you must first try what electrotherapeutics can do for the cure of the fundamental disease, the constitutional neuropathia, neurasthenia, hysteria, anæmia, &c. (by means of general faradisation, central galvanisation, electric baths, &c.) You must then find out whether marked vasomotor disturbances are present or not during the attack; and if they are then the method of treatment of the sympathetic which was developed by Holst after the rules of polarity must be begun, according to whether spasm or paralysis is present. In the *angiospastic form* of migraine, where the face is pale and cool, the arteries small and hard, the pupil and the interpalpebral space enlarged, and the pain increased by compression of the carotid, you will proceed to employ the stabile, long-continued action of the anode on the cervical sympathetic (the kathode being in the hand or on the nape of the neck) for from 2 to 5 minutes, the current being begun and ended gradually. In the *angioparalytic form*, on the other hand, with flushed, hot face, pulsation of the dilated arteries, hyperæmia of the retina, contracted pupil and interpalpebral space, with relief of the pain during compression of the carotid, the kathode is to be applied to the cervical sympathetic, and a moderately strong current to be passed through for one or two minutes, which must be repeatedly opened and closed, and perhaps reversed once or twice; but too strong irritation must be avoided, or the vessels will become still more dilated.

Engelskjön treats the angiospastic forms with the faradic current and the angioparalytic with the galvanic, passing the current from the medulla to the region above the larynx, apparently with brilliant results. C. W. Müller speaks highly of galvanisation of the cervical sympathetic and of the nape of the neck, generally with the anode, but sometimes with the kathode, stabile, the action of the current being stronger and more prolonged (density $\frac{1}{7}$, duration 2 to 3 minutes) in the spastic and shorter in the paralytic form.

If no distinct vasomotor disturbances are to be made out you may still try first one and then the other of these methods of Holst's; and I have, besides, found the simple transverse and longitudinal passage of the current through the head to be of service, combined with the usual galvanisation of the sympathetic. Moritz Meyer cured a case by treating the points on the cervical part of the spine which were painful on pressure.

Finally, you may also try the *faradic current*, either in the form of weak, long-continued faradisation of the head, preferably with the electrical hand, or in that form of 'swelling faradic currents' so extraordinarily vaunted by Frommhold. The *primary* faradic current, which must be suitably weakened by means of a tube of water, is to be passed from the nape of the neck (anode) to the forehead, or to the spots, on the temples or elsewhere, which are regularly affected with the pain, large, flat sponge electrodes being used. You must begin with a very gentle current, increasing it slowly and gradually until the perception of it in the head is intense; this you will do for 3 to 5 minutes daily.

All these methods of treatment must be continued at intervals for a long time, generally for months or even years, if they are to have permanent results; and improvement or cure cannot be considered to have taken place until, on the usual occasions, well known to the patient, especially during menstruation in women, the attacks either no longer come on or are at least much diminished in number and intensity.

The *electrical treatment of the attack itself* is generally quite useless, scarcely producing a momentary relief. Still Holst reports some favourable results with his method in attacks characterised by well-marked vasomotor symptoms, which he was able to cut short; and Frommhold also claims to have frequently achieved, with his method, temporary improvement, lasting for some hours. I myself have hardly ever been so fortunate, but quite recently, in a case of very severe (anomalous) migraine, I succeeded, to my great astonishment, in producing a magical effect on the agonising pain with the galvanic current. Still these are exceptions, and electricity is no sure palliative for attacks of migraine.

4. *Cervico-brachial neuralgias*, in their various forms, come often enough before the eyes of electrotherapeutists, and the selection of the suitable methods of treatment presents no difficulty. The results too in most of the rheumatic, neuritic, and such like brachial neuralgias are generally very satisfactory; still we may sometimes stumble upon unexpected resistance, and here of course, as everywhere, the severe symptomatic neuralgias are entirely unfavourable.

The choice of the methods of treatment is to be made according to our general rules—in the first place, if possible, causal treatment; then, according to inclination, the *faradic* current, passed longitudinally through the principally affected nerve trunks; or the faradic brush to the affected nerve region itself, or to the spinal column in the region of the point of exit of the spinal nerves concerned. With the *galvanic* current the painful points which may be present in the spine, in the plexus, or in the affected nerves themselves, must first be sought out and treated with the anode stabile, the kathode being on the sternum or on the back. In many such cases the treatment of the brachial plexus in the supraclavicular space with the anode (current gradually made and broken) is important. Subsequently descending stabile currents may be tried, the anode being on the plexus and the kathode on the peripheral nerve trunks, especially on any tender spots which may be present. If some improvement is gained by this treatment the symptoms of stiffness and weakness of the arm muscles which may remain behind can be removed by means of a few kathodic closures or labile treatment. Where there is any complication with paralysis you must first conquer the neuralgia and only then attack the paralysis.

5. *Intercostal neuralgias*, which sometimes occur in a very obstinate form, are generally less favourable for treatment. The rheumatic, neuritic, and traumatic forms are generally comparatively favourable ; but, on the other hand, the intercostal neuralgias caused by vertebral disease (caries, carcinoma), meningeal tumours, pulmonary phthisis, tabes, and the like are very obstinate and often incurable, and the forms which occur in connection with herpes zoster in old people are often of surprisingly long duration.

If the causal treatment is unsuccessful intercostal neuralgia may be relieved by the faradic current; but the galvanic current is often more effectual, applied either with the anode on the different painful points or successively along the whole course of the nerve (the kathode indifferently placed and the current strong), or else with the anode on or near the spine and the kathode on the several painful spots laterally and anteriorly. *Mastodynia*, which is only a subform of intercostal neuralgia, must be treated in exactly the same way.

6. *Neuralgia of the lumbar plexus*, with its varieties (crural, lumbo-abdominal, obturator, and lateral femoral cutaneous), is to be treated according to the same rules as sciatica, of which we shall speak immediately. In cases where it does not proceed from serious disease of the spine, the psoas, the pelvic organs, &c., it yields, as a rule, quickly and promptly to electrical treatment. As a necessary condition of success the nerve region which is affected must be determined with as much certainty as possible. The more obvious method of treatment is a descending stabile current from the spine (anode) to the affected nerve trunks themselves ; the stabile action of the

anode on the spine and then on the nerve trunks and their principal painful points (the kathode being on the posterior surface of the thigh or on the knee); or the faradic current may be employed in the usual manner. If the saphenous nerve is implicated it may sometimes require separate treatment in the leg. A few kathodic closures or labile excitation at the close of the treatment appear to be of some effect.

7. *Neuralgia ischiadica*, or *sciatica*, one of the most frequent of all the neuralgias, is accessible to electrical treatment in very many cases, and interests the electrotherapeutist in a great variety of ways. Cases of sciatica are of daily occurrence in the out-patient clinics frequented by the working classes, but it is not unknown in other ranks. Individual cases differ very much among themselves in respect to ætiology, localisation in the different nerve tracks, the intensity and the curability of the affection; and the *results* are, consequently, very varying. They are always favourable in the rheumatic and neuritic forms of sciatica, especially in recent and slight cases, and also in neuralgias resulting from articular inflammation and injury; but much more uncertain and frequently entirely negative in the symptomatic forms proceeding from pelvic, vertebral, and spinal diseases. If you obtain any relief in individual patients it is only exceptional, and you will very soon give up the electrical treatment as useless.

The *methods of treatment* are the usual ones, modified by the deep position and the great extent of the nerve, and perhaps also by the seat of the lesion. The *galvanic current* must always be tried first in the rheumatic forms which are so frequent, and, in consequence of the great length of the nerve, first the *descending stabile current*, the anode being placed on the sacrum, in the neighbourhood of the plexus, or near the sciatic foramen (if that is the chief seat of the lesion), and the kathode resting lower down the nerve on the several painful points or on the chief branches. According to Remak it is advisable to include separate sections of the nerve, of about 20 to 25 centimetres long, in the current circuit, and in that way to proceed gradually down the nerve from the sacrum to the foot (as, for example, first from the sacrum to the sciatic foramen, then from there to the patella, and lastly from the patella to the malleolus or the ankle joint), and at each situation to let the current act stabile for from 1 to 3 minutes. After some improvement has been attained a few closures of the current or a short labile application may be made, which will be the best means of removing the stiffness and heaviness which may be present in the muscles. The deep position of the nerve and the great resistance of the skin in the parts concerned (with the exception of the neighbourhood of the knee joint) require strong currents and large, disk-shaped electrodes, especially when we have to do with very corpulent individuals. The duration of the whole sitting should be 4 to 10 minutes. It is often necessary to follow up neuralgia as far as the individual twigs of the nerve by direct treatment of them.

I have often obtained equally good results with the purely polar method, by allowing the anode, stabile, to act on the different sections of the course of the nerve (lumbar vertebræ, plexus, sciatic foramen, painful points), the kathode being placed on the anterior abdominal wall or on the thigh; strong currents are necessary here also, and some interruptions are often useful in increasing the action. What Remak has employed under the name of 'circular currents' (fixation of the anode on the seat of lesion or of pain, whilst the kathode is applied successively to a great number of points in a circle round the anode) suits well in connection with this polar anodic treatment.

In particularly obstinate cases you must include the sciatic plexus as directly as possible in the region of greatest current density, and so reach the lesion more thoroughly, by introducing one electrode into the rectum and applying the other to the sacrum and the lumbar region. Ciniselli recommends the continuous wearing of a simple galvanic element as effectual against sciatica. It may be fastened to the leg and the sacrum, and worn for days and even weeks together.

Treatment with the *faradic current* has given very good results; it is carried out in the usual way, either with the passage of a strong faradic current through the nerve trunk and its twigs themselves or with the employment of the faradic brush to the skin of the sciatic region, and the faradic moxa over the sciatic foramen, the sacrum, the lumbar vertebræ, &c. Seeger has also employed the galvanic brush with good effect.

Any special symptoms which may be present—anæsthesia, paralysis, or muscular twitchings and spasms—require a special treatment according to the general rules already laid down.

All other forms of sciatica must be treated according to the same methods, except that in many cases, such as, for instance, tabes or other spinal affections, a specially causal application may be added.

Neuralgias of the urinary and genital organs (pudendo-hæmorrhoidal, spermatical, urethral, ano-vesical varieties), which certainly belong to the sacral plexus, are rare occurrences, about which there are not yet sufficient electrotherapeutic experiences. Of course galvanic and faradic currents may be employed in these forms, often with great benefit, and it will not be difficult for you to determine the suitable method for each individual case and then to have recourse to it. This holds good also for the so called coccygodynia, in so far as it is really of a neuralgic character, and thus suitable for the employment of electricity. In this form some favourable results have been obtained (Seeligmüller).

8. *Neuralgias of the joints* (articular neuroses) also deserve a short notice in this place. These belong, without a doubt, partly to the true neuralgias, although they are developed, in the great majority of cases, on a hysterical basis, so that their treatment forms a part of the treatment of hysteria (Lect. XXXI.) They occur most frequently in the knee and hip joints, more rarely in the wrist, ankle and shoulder joints. They may exist alongside of all the classical symptoms of hysteria, but may often present great difficulties of diagnosis from inflammatory, carious, and fungoid processes in the joints. However in all such cases an attempt at electrical treatment can never do any harm, while the rapid results of the experiment may sometimes lead to confirmation of the diagnosis.

The various antineuralgic methods of application of electricity may also be of service in articular neuroses. Besides the treatment directed against the fundamental affection you may employ the transverse passage of weak and afterwards strong galvanic currents through the diseased joint; or the isolated action of the anode stabile upon it, with the help of large sponge electrodes or wet compresses, surrounding the whole joint and serving as the anode, the kathode being fixed elsewhere. You may also act with small electrodes on the painful spots about the joint and on any tender points which may be present in the spinal column; and an anodic treatment of the nerve trunks belonging to the joint may also be of service. If this is not effectual you may send strong faradic currents transversely through the joint, or allow the faradic brush to act energetically upon the skin over the joint, the painful spot, or the corresponding portions of the spine. The experiences of O. Berger and Moritz Meyer, which I can in part confirm, teach us that occasionally results, sometimes even very striking and satisfactory, may be obtained by all these methods. Frequently, however, you will be obliged to treat such cases for a long time, and even then be disappointed in the result.

106. *Observation by Berger. Articular Neuralgia.*—A peasant woman, aged 38. Increasingly severe pain in the knee joint after a contusion. Rest in bed, vesicants; enveloping in cotton wool, &c., only increased the affection, which was complicated, later on, with muscular twitching and formication. Condition after 4 weeks: Limping, pain in the knee, no external anomaly in the joint, painful contraction of the flexors, tibial nerve painful on pressure, extreme cutaneous hyperalgesia of the knee joint and the lower third of the thigh. Treatment: Faradisation, anode on the knee cap; faradic brushing of the skin over the knee and its neighbourhood, with a strong current, for 4 minutes; faradic moxa to a painful spot near the patella. Immediately afterwards patient could walk for half an hour without pain. Another sitting the next day, although the symptoms had disappeared. The cure was maintained.

107. *Observation by Berger. Articular Neuralgia.*—An anæmic and nervous lady, aged 45. Contusion of the right knee in December 1872. After several weeks severe pain in the joint, radiating upwards and downwards and defying all treatment, finally affecting the left knee also. Bandaged for 8 weeks in bed, without improvement. In July 1872 cutaneous anæsthesia and analgesia of the right knee joint, with frequent formication; point painful on pressure at the head

of the fibula on both sides, as well as in the right knee-cap. The patient could only walk a few steps, supported, and with the most acute pain. Treatment: *Stabile galvanisation* of both knee joints, with a moderately strong current, for 8 minutes. Considerable improvement immediately after the sitting; after 7 sittings cure of the affection, that had lasted many months. Cure remained permanent.

9. The so called *visceral neuralgias* present so much that is obscure and uncertain in their nature and onset that it is difficult to approach them with rationally founded therapeutical suggestions. Their occurrence is so often connected with the simultaneous presence of serious anatomical changes in the organs concerned (heart disease, aneurisms, atheroma, gastric ulcer, carcinoma, &c.), or else it is so difficult to separate them with certainty from such affections, that a certain obscurity in their therapeutics is only too easily explained, and we must generally limit ourselves to palliative measures. Electricity, therefore, has only been employed timidly in such cases, and the methods are by no means developed to any great extent. This depends on the fact that we are generally ignorant in which nerves (fibres or centres)—whether in the sympathetic, or in the cerebral, or in the spinal system—these neuralgias have their seat, and whether they have a peripheral or central origin.

But if you are certain of the diagnosis of such a neuralgia you may always try electricity, as our most important antineuralgic remedy; and this must be done according to the general rules, the methods of application being liable to numerous little modifications, according to the position of the diseased nerve regions and the views regarding the actual seat of the affection.

Neuralgias of the pharynx and larynx are by no means rare, according to the most recent observations of Jurasz. Hyperæsthesia and paræsthesia of these structures, requiring the same therapeutical measures, are much more frequent. If you have convinced yourself of the absence of all grosser changes in the pharynx and larynx, or have tried in vain all the usual local remedies, an attempt with the electric current is certainly justifiable. Various ways may then be tried in turn—

the transverse passage of a stabile galvanic current through the larynx and the neighbourhood of the pharynx, or a stabile current from the nape of the neck to the angle of the jaw and the larynx, or the stabile action of the anode on the larynx, the kathode being on an indifferent point, e.g. the dorsal vertebræ. The faradic current may be employed in the same way, with moist electrodes, but in many cases the faradic brush, applied to the region of the larynx and pharynx, acts much more powerfully, and it commends itself specially for hysterical and hypochondriacal hyperæsthesia and paræsthesia. You must not think of the endopharyngeal or endolaryngeal use of the current in such cases.

Neuralgia of the nerves of the heart, angina pectoris, occurs much more frequently, and appears in many cases with the well-marked features of a true neuralgia; but still it is very difficult to determine how much is purely sensory irritation and how much motor stimulation as well, whether this latter is produced directly or reflexly, whether the affection has its seat in the vagus or in the sympathetic tract, &c.

Those forms and those attacks in which the neuralgic symptoms come to the front will specially be the subject of electrical treatment, even although by the more recent experiences of von Ziemssen the possibility of a direct action on the motility of the heart appears to lie nearer at hand (vide sup. p. 121). Any affection of the heart or of the large vessels which may possibly be present does not preclude the trial of electricity, as by the reasonable employment of it no harm can be done, and at least a palliative effect may be produced.

The most varied applications of the electric current have been tried; Duchenne first recommended the use of the faradic brush as a powerful cutaneous irritant; he faradised the neighbourhood of the heart, and especially the nipple, with intense currents, and has cut short attacks in several cases in this manner, sometimes even producing a cure by continuing the use of this procedure.

108. *Observation by Duchenne. Angina Pectoris (Idiopathic).*—A tanner, aged 50, formerly healthy. Noticed suddenly, in November 1852, a deep-seated burning in the breast, with radiating pains in the left arm, combined with formication, palpitation of the heart, oppression

in the chest, great feeling of anxiety, bent position. Relief in 18 hours after bleeding. Attacks occurred on the least provocation, with every movement or agitation, even in the horizontal position. Gradual diminution in the number and severity of the attacks, but patient condemned to almost absolute rest. Heart and lungs perfectly normal in repose; attack produced by any movement, even a simple bending forwards; acute pain with a feeling of constriction below the upper part of the sternum, radiating towards the left arm, with formication in that situation. Position bent forwards, pain increased by walking. Respiration short and tumultuous, severe palpitation, abundant perspiration, expression of great anxiety in the face, &c. Duration of the attack 8 to 10 minutes. At the beginning of one of these attacks (April 1853) a strong faradic current was directed on the nipple by means of two metallic electrodes; with the frightful pain which this caused the symptoms in the chest disappeared immediately, and the patient returned to his normal condition. It was now much more difficult to induce a second attack, and when this was at last done it was also immediately cut short by the electrocutaneous irritation of the upper part of the sternum. Marked improvement on the following day; considerable exertion required to induce an attack, which was stopped in 2 or 3 seconds by means of faradocutaneous irritation of the thorax. No more attacks from that day forward; 4 or 5 more applications, in about 14 days, made the patient completely and permanently capable of work.

The direct faradisation of the cardiac region with large electrodes (transversely from the heart to the spine), or the faradisation of the cervical cord, the vagus, and the sympathetic in the neck, though it deserves less confidence, may yet also be tried.

Eulenburg, on the other hand, expects specially favourable results from the *galvanic current.* It also may be employed in a great variety of ways. The most obvious is the stabile action of the anode direct to the neighbourhood of the heart and the region of the cardiac plexus (with large disk-shaped electrodes), the kathode being placed opposite, on the spine. Eulenburg places the anode on the sternum, the kathode on the lower cervical vertebræ. The next thing to be done is to influence the large nerve trunks in the neck (vagus, sympathetic), either by placing the kathode on the cardiac region and the anode on these nerves, or after the manner of the ordinary galvanisation of the sympathetic, or with an ascending current from the lower to the higher cervical sympathetic ganglion, from which Löwenfeld has lately reported good results. In any case it appears to me important regularly to include in the treatment the cervical cord in its whole extent, as well as the medulla oblongata; but you may try various methods. Galvanisation of the sympathetic is also frequently successful in the so called vasomotor angina pectoris; von Hübner had good results from it in his case.

109. *Observation by von Hübner. Angina Pectoris.*—A landowner, aged 47. Taken ill, after a fatiguing journey in an open post-chaise, with dyspepsia and a tight feeling in the cardiac region; a few days after (March 16) the first really sharp attack of angina pectoris, recurring in the following week from 1 to 4 times daily, in part very severe and lasting for about 3 hours. Remedies generally without any result. On March 25 the first galvanic treatment, ascending to the cervical sympathetic; then the kathode on some of the painful spots in the back, and labile and stabile over the cardiac region, the anode on the third ganglion. From this sitting onwards the attacks ceased and did not return. Twelve more applications were made.

The choice of the strength of the current must be made with a certain amount of caution, and both it and the length of the sittings must be increased very gradually indeed. Eulenburg advises the avoidance of strong stimulation of the skin where signs of irritation of the vagus and of paralysis of the vessels have shown themselves; but the method of procedure requires to be more thoroughly elaborated. I have quite lately seen good palliative results, lasting for a number of months, in a very severe case of angina, from the galvanisation of the neck and directly to the heart.

In *neuralgia of the gastric nerves—cardialgia* or *gastralgia*—we are generally in uncertainty, in the same way as in angina pectoris, as to whether the affection has its seat in the vagus or in the sympathetic, and whether changes in the stomach (ulcer, commencing carcinoma, &c.) may be at the bottom of it or not. Leube has for this reason recommended electricity as a help to the diagnosis. There are always not a few cases (in hysteria, neurasthenia, chlorosis, &c.) in which the true nervous nature of the affection cannot be doubted for a moment, and in which a trial of electricity appears to be indicated. This plan is strongly recommended by Leube and its very great success extolled; he places the anode on the epigastrium, and especially on any painful spots which may be present, and the kathode in the left axillary line or more towards the spine; and allows a strong stabile current to pass through for from 5 to 10 minutes. Vizioli has also recently cured a very severe hysterical gastralgia by the action of the anode, the kathode being in the hand.

110. *Observation by Leube. Gastralgia.*—A foreman, aged 40, a vegetarian. Weight in the epigastrium for 3 weeks, alternating with pain, which reached to the back, disappeared on lying, and came on with gurgling when particularly severe. No effect from eating; appetite good, no vomiting. A painful, tender spot, about the size of a florin, in the gastric region. Diagnostic uncertainty between ulcer and gastralgia. Galvanic treatment: Anode on the painful spot in the epigastrium; immediate disappearance of the acute pain. The same effect with each repetition of the galvanisation. Recovery after a few weeks.

Here also the treatment of the spinal cord or of the sympathetic and the vagus in the neck may be tried with advantage. Beard specially recommends his 'central galvanisation' (vide Lect. XIV.) as a sovereign remedy against nervous cardialgia. Direct faradisation of the gastric region or faradic brushing of the epigastrium are also indicated as alternative methods.

Neuralgia of the intestinal nerves, enteralgia, colic, may be looked at from the same points of view as gastralgia; there is, as yet, very little experience available as to its electrotherapeutics. It is difficult here also to divide true, nervous colic from those other forms occasioned by disease of the intestine, foreign bodies, worms, &c. You will have recourse to electrical treatment most readily in the case of hysterical patients, while the most frequent form of colic—lead colic—generally yields so quickly to other suitable treatment that the eventual electrical treatment scarcely ever comes into question at all.

If you wish to try it you may apply the anode, first of all, stabile, to the abdomen, on the specially painful points or in the neighbourhood of the cœliac plexus and the abdominal aorta, with large, disk-shaped electrodes; you may also place the anode on the dorsal vertebræ in the region of the splanchnic nerves (from the 6th to the 12th dorsal vertebræ), the kathode being on the abdomen, with a tolerably strong current.

The same points of application are suitable for the faradic current, applied by means of moist electrodes; while the skin of the abdomen, especially at the epigastrium and the groins, is most suitable for the application of the faradic brush.

In *lead colic* especially it has recently been recommended to induce a stool by introducing one electrode into the rectum and passing the other over the whole abdominal surface with strong faradic currents, and thereby to arrest an attack of colic.

111. *Observation by Rothe. Saturnine Colic.*—A typefounder. Severe lead colic for 6 days, with complete constipation. Injections of morphia and the strongest drastic purgatives quite ineffectual, likewise enemata of soapsuds. Treatment: A long rectal electrode introduced as high up as possible, and the other, broad sponge electrode, applied labile over the abdominal walls and to the lumbar vertebral column, a *strong faradic current* being passed through for 8 or 10 minutes. Pain almost disappeared after this application; a few minutes later an enormous evacuation occurred with the removal of all discomfort. The attack was over.

Finally, there remain certain *neuralgias in the neighbourhood of the pelvic nerves* to be mentioned, among which we may reckon a number of painful affections which are known under different names, such as neuralgia hypogastrica or uterina; hysteralgia; dysmenorrhœa; neuralgia spermatica, urethralis, ano-vesicalis, &c. Certain cases of vaginismus, and certainly also 'ovarie' (ovarian hyperæsthesia), may be counted in this category. None of these affections have yet been properly or exhaustively studied by electrotherapeutists, and still less by gynæcologists, within whose province these forms of disease generally fall; but it is likely that in them there is often something to be gained by electrical treatment. Neftel has recently made the attempt to manage them all from a single point of view, and indicates a method of galvanic treatment, to which he ascribes great results. He calls it 'galvanisation of the genito-spinal centre and of the splanchnic nerves,' proceeding from the hypothesis that the therapeutical result depends essentially upon the influencing of these parts. The method is the following: The anode is applied to the back, over the lumbar enlargement, and the kathode in the middle of the hypogastrium, close over the symphysis; a few reversals of the current are made next; the current is diminished, and the anode passed slowly up and down along the whole spinal column. The kathode is then placed first on the one, then on the other inguinal region, and the same procedure carried on with the anode and with repeated reversals. This energetic method is said to be specially suitable for severe attacks of dysmenorrhœa, and is said to remove the pain at once, or at all events to diminish it greatly. After the cessation of the menses it should be continued in a milder manner, with weaker currents, for a long time (1 to 3 months). Neftel also recommends exactly the same procedure, with a corresponding alteration in the points of application, for the other visceral neuralgias. He adds, however, by way of caution that the strong currents and the reversals are not well borne by hysterical patients. Holst has also treated a case of dysmenorrhœa according to this method with good results. Pregnancy is of course a contra-indication.

The attempt may also be made to reach these neuralgias with the faradic current, by means of the two usual methods of application. Heinlein has cured a spermatic neuralgia very quickly by means of a weak faradic current (electric hand).

Von Holst has employed galvanic treatment with good results in ovarian pain, by placing one pole on a painful point in the spine and the other on the tender ovary; this ought to be tried further, in view of the importance of this symptom in hysteria.

Neftel has described as *rectal neuralgias* conditions of great pain and unpleasant sensations in the rectum, coming on after each defæcation and lasting for many hours, everything being found perfectly normal on examination; and he has treated this also, with good results, by means of his method, just described. A similar condition occurs in the bladder and urethra after micturition.

VI. *SPASM AND CONTRACTURE.*

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LECTURE XXVIII.

Introduction—Nature and Pathogenesis of Convulsions—Spastic Changes—Electrical Irritability—Electrotherapeutic Problems—Removal of Direct Motor Irritability—Removal of Reflex Irritation—Introduction of Strong Restraints—Cases—Electrotherapeutic Methods — Causal Treatment — Direct Antispastic Treatment and its Methods, Galvanic and Faradic—General Plan of Treatment—Results—Separate Forms of Spasm—Spasm of the Muscles of Mastication—Imitative Facial Convulsions—Blepharospasmus—Spasm in the Region of the Accessorius and in the Nape of the Neck—Spasm in the Muscles of the Trunk—Respiratory Spasms, Singultus, &c.—Spasms in the Upper and Lower Extremities.

Gentlemen, in turning now to the consideration of the electrotherapeutics of spasm and convulsions I enter upon a subject which has certain analogies with, but is much more complicated than, that of neuralgias. The theory of spasm forms one of the most obscure chapters in the pathology of the nervous system, and in many of the wonderful forms of disease which belong to it we are still without any certainty as to the seat and nature of the fundamental lesion and the finer processes which determine the peculiar character of the affection; we know little of the relation of spasms to the numerous causes of their mode of origin—in a word, of their pathogeny.

It is clear that this undeveloped and, in many essential points, still highly deficient *pathology* of spasms touches their *therapeutics*, and especially their electrotherapeutics, very closely, and is calculated to restrain its scientific development at every step. Our procedure, indeed, rests here upon a very insecure foundation: the methods are not developed to any reliable extent; the results are sometimes unexpectedly good, sometimes equally unexpectedly negative, and the electrotherapeutic successes in spasms are far behind those in neuralgia. We must, therefore, approach this branch of the subject, almost more than any other, with some hesitation; there is much room here for accurate therapeutical investigations.

We must first occupy ourselves with the consideration of spasm in general, and then with the cases in which more or less localised spasms have acquired a certain independence and occur as separate forms of disease, and with those in which such local spasms only appear as symptoms of grosser local diseases of the nervous system. On the other hand, I will reserve for future lectures the consideration of those forms of spasm which are described as the so called general neuroses or as central (functional) neuroses in nervous pathology (chorea, epilepsy, tetanus, paralysis agitans, &c.)

It is necessary here also, for the foundation of electrotherapeutic methods, to discuss briefly the *nature* and *pathogeny* of spasms. If we define them as 'involuntary muscular contractions, induced by pathological processes' (certainly not a very exhaustive definition), we express the fact that we have to do with abnormal irritative processes—abnormal in their occurring either at all or with the intensity then present—in the motor apparatus in its widest sense, muscles, motor conductive tracts, motor and reflex centres. But of what nature the nutritive or histological changes in these apparatus are which induce the abnormal irritative process, or invariably accompany it, we know in most cases absolutely nothing. The simplest observation shows that the spasm can certainly not be generated by any coarse anatomical changes, for these are always and without exception followed by paralysis; and even when we find—as is not unfrequently the case—grosser anatomical lesions in spasmodic diseases, we may always assume with some certainty that they have not affected the motor apparatus itself, but are only present in its neighbourhood, and so exercise an irritative influence upon it. If paralysis and spasm occur simultaneously in one and the same motor tract, it must be assumed that the paralysing change affects a more central portion of the tract than that causing the spasm. We are, therefore, driven to the assumption that no severe anatomical lesion can lie at the bottom of the spasms, but that we have chiefly to do with finer (molecular, nutritive, circulatory) changes, which may be set up in many different ways. And if we consider more carefully the relations of many spasms to their causes, the thought forces itself upon us that these causes frequently do not directly establish in the nerve the morbid excitation which causes the spasm, but that they first occasion, by their presence, a special and peculiar change in the motor apparatus, a kind of 'spastic change,' perfectly analogous to the formerly mentioned 'neuralgic change,' which represents the nature of the spasmodic disease and induces the individual spasms and spasmodic attacks. But these are as yet only more or less plausible conjectures.

With respect to the *pathogeny* of these pathological irritations we may say that they owe their origin either to the abnormal magnitude of the irritation or to an increase in the irritability of the motor apparatus itself. In many, perhaps in most, cases it will not be possible to separate these two causes definitely from each other. Both are often present; but it is likely that the rise of the irritability plays a more important part in the pathogenesis of spasm than the increase of the irritation, and that what I have just designated the 'spastic change' in the motor nerves may not, in the end, be very different from such an increased irritability. But in what way this irritable condition is modified, in order to produce the various kinds of convulsion (tremor, spasm, tetanus, contraction, clonic convulsions, &c.), we have no means at all of knowing.

The abnormal irritative process may seize upon the motor apparatus *directly*, as upon the muscular fibres themselves and the motorial end-plates (fibrillary contractions, certain forms of permanent contraction, myotonic disturbance); or upon the peripheral tracts (by means of neuritis, traumata, &c.); or upon the motor tracts and the central apparatus in the spinal cord (in myelitis, spastic spinal paralysis, &c.); or, finally, upon the various constituent parts of the brain (in apoplexy, tumours, inflammation, &c.) I would only remind you of Nothnagel's convulsive centre in the pons, and especially of the new discoveries with regard to the cerebral cortex, which certainly induce us to believe that we must localise in it a large number, probably, of forms of spasm which are still very obscure.

But, on the other hand, the irritative process in spasm is often induced *indirectly*, and most frequently *reflexly*, either through the abnormally irritable condition of the sensory terminal apparatus and tracts (as in disease of the sensory nerves themselves, in irritation of highly nervous surfaces—the skin, the mucous membrane, the retina, &c.) or through the abnormally increased irritability of the reflex centres in the brain and spinal cord, which convert normal physiological stimuli into morbid centrifugal irritations (as in myelitis, tetanus, &c.)

The question as to how far the *impairment of the inhibitory mechanism* may be answerable for the pathogeny of spasm cannot be investigated further at this stage, for the knowledge which we have as yet of the localisation, the nature, and the mode of action of this mechanism is not sufficient to exert much influence on our electrotherapeutic measures. I will only add that the simultaneous presence of general neuropathic dispositions or affections is necessary for the production of spasms, even of many which are entirely local, and that without such favouring predisposition very many local spasms will not be developed even with definite determining causes. This holds good for general neuropathic affections, for hysteria, for neurasthenia, as also for anæmia and chlorosis and other influences which weaken the nervous system; and this must be taken into consideration in the treatment.

This is, of course, not the place to enter, however shortly, on the symptomatology and diagnosis of the several forms of spasm. I must not, however, omit to say that it is quite indispensable, for successful treatment and the inauguration of therapeutical indications and methods, that you should acquire the most accurate knowledge as to the nerve-muscle regions affected by the spasm (for very important mistakes sometimes occur—e.g. confusion as to which side of the body is affected, as in spasm of the cervical and occipital muscles). Further, you must use every endeavour to find out whether you have to do with a directly or reflexly engendered spasm. In the first case you have to determine the exact seat of lesion by means of all your diagnostic methods; in the second case to discover, with the greatest care, the sensory nerve-regions from which the morbid stimulus proceeds. In this connection I would specially remind you of the spasm-exciting or spasm-inhibiting pressure points of von Graefe, Remak, and others, which are of so much importance for electrotherapeutics.

Unfortunately I am obliged to confess that *electrical* *examination* has as yet contributed nothing, or next to nothing, towards the elucidation of all these important subjects. In very many cases, especially those which are uncomplicated, no alteration whatever in the electrical excitability can be found; in other more complicated cases changes occasionally occur, which belong to the accompanying paralysis and have, therefore, nothing to do with the spasm. There is no peculiar change belonging to the spasm as such. Only in the rarest cases, and with accurate quantitative examinations, the earliest expected change—an increase in the electrical excitability—can be made out. It is only in tetany, as I first established it in a definite manner, that this has been done with any regularity; I have never been able to confirm it in chorea. At all events other and finer methods of investigation would be needed in order to decide upon the characteristic changes in spasm. The apparent lowering of the electrical excitability which often occurs in contracted nerve-muscle regions, from the fact that weak stimuli do not affect the already contracted muscle, must not be regarded as a true diminution. The remaining details, not important in themselves, will be gone into in connection with the separate forms. Now and then it may be possible to prove the presence of points tender on pressure by means of the electrical examination; in difficult cases, therefore, you should never omit this test (with the kathode on the spine, the plexus, &c.)

After these introductory remarks you will have formed an idea of the tasks set before the electrotherapeutist and of the means by which they are to be fulfilled; I need only indicate them very shortly. In the first place we strive after the *removal of the direct irritation*: this may be done by lowering the irritability by the anelectronising of the motor apparatus and the modifying action of the electric current; by the removal of pathological irritation from the neighbourhood of the nerves (hyperæmia, inflammation, cicatrices, &c.), for which we employ the vasomotor and katalytic actions of the current; or we endeavour to utilise both categories of action, in order to remove the hypothetical molecular or nutritive disturbance—the spastic change—in the motor nerves.

A second task consists in the *removal of the spasm-exciting* *reflex irritation.* This may be done in the same way as in neuralgias and other sensory irritative conditions, and also by means of the modifying and katalytic actions of the current. To this belongs also the treatment of certain pressure points, so effectual in many cases and the mechanism of which is still rather obscure.

Finally, we have yet another method of removing spasms —the *introduction of inhibitions*, by means of which the motor irritative process may be subdued and stopped. This may be done by strong peripheral sensory stimulation—the stimulating action of the current.

You will hear later how this latter may be employed to produce, by means of over-stimulation, a kind of weariness and exhaustion of the motor apparatus, and thereby solution of the spasmodic conditions, and also to remove secondary, nutritive disturbances (shortening, atrophy, &c.), which are sometimes developed in muscles which have been long affected with spasm.

It is also evident that the different actions of the current may be employed to fulfil the causal indications, to remove the fundamental affection causing the spasm, the neuritis, myelitis, grey degeneration, hysteria, neurasthenia, &c. This is often connected with the direct antispastic treatment, and sometimes forms the most important part of it.

In spite of these numerous sources of help which the electric current appears to afford us the electric treatment of spasms presents much greater difficulties and uncertainties than that of neuralgia. The results are not nearly so brilliant nor so sure; they depend more upon chance than upon the skill of the electrotherapeutist; and frequently the affections show a surprising obstinacy, however harmless they may have appeared at first.

Still there are always to be found in literature and in practical experience many examples of the successful electric treatment of the most varying forms of spasm. I will now quote a few, in order to show you with what difficulties treatment often has to contend, but also with what various methods the spasms may be overcome, and how surprising the results sometimes are.

112. *Personal Observation. Spasm of Left Facial* (*Convulsive Tic*).—A compositor, aged 48. Had suffered for 10 days from a sudden and apparently causeless mimical spasm of the left side of the face, which occurred in frequent and characteristic attacks. Otherwise perfectly healthy. Galvanic treatment first tried (A, stabile, on the plexus anserinus, stabile from the nerve trunk to the muscles; later also galvanisation of the sympathetic). No improvement, rather aggravation (12 sittings). Two months' pause in the treatment; gradual improvement to 8 or 10 attacks in the day. Resumption of the galvanic treatment; increase of the attacks within the next 10 days to about 25 in the day. Morphia injections for 4 weeks, without result. Then employment of the '*swelling*' *faradic current*: after the 5th sitting the number of attacks reduced from 12 or 16 to 5 or 7 in a day; after the 11th sitting only 3 in the day; in the days following the 12th sitting only 3 attacks in all, and then a complete cessation of them.

Patient perfectly free for 2 years; came again in March 1870, having had facial spasms for 8 days, 20 or 30 attacks in the day. Treatment now begun with wavy faradic currents; no improvement in the next 6 days. Then galvanic treatment, A stabile, with gradual onset and cessation. No result in 15 sittings, rather an increase, up to 50 or 60 attacks daily. Then again swelling faradic currents; in 10 sittings no results, attacks remaining at from 30 to 45. Then pot. iod. for 3 weeks; gradual diminution to 6 or 7 attacks daily. Again 14 sittings with the same faradic currents, and again no result (12 or 15 attacks daily). Administration of valerianate of zinc in large doses, and final disappearance of the spasms in 14 days.

In January 1873 repetition of the affection, but only to a moderate degree (3 to 6 attacks in the day); exactly the same reaction in the branches of the facial on both sides on electrical examination. Electrical treatment of the most varying kinds without any noteworthy influence on the affection. Disappearance of the patient from observation after 2 months.

113. *Personal Observation. Double-sided Mimical Spasm of the Face* (*Blepharospasmus*).—A peasant, aged 24. For 3 months severe blinking, coming on with burning in the eyes and great photophobia, gradual increase up to intense twitching in the face. Affection already improved by ophthalmological treatment (Prof. O. Becker). Condition on Nov. 16, 1870: Frequent attacks of double-sided histrionic facial spasm; first repeated strong contractions of the eyelids, then wide opening of the eyes, energetic contraction of the frontalis with simultaneous lively contraction of the oral muscles. Attacks every

2 or 3 minutes. Otherwise perfectly healthy. Galvanic treatment: A stabile on the eyes (K in the nape), then A stabile on the plexus anserinus on both sides. Next day considerable improvement; attacks much less frequent; after second sitting attacks nearly disappeared; cure after the 5th sitting.

In March 1873 reappearance of patient with the same affection, which had come on 3 months before, after a long walk in the snow. Not so severe as before. Attacks of the same nature, but not so acute; no pressure points noticeable. Galvanic treatment repeated; cure in 2 sittings.

114. *Personal Observation. Left-sided Histrionic Facial Spasm.*—A young lady, aged 23. Operation on the left eye for strabismus at Easter 1866. In spring 1867 gradual development of convulsions on the left side of the face, increasing gradually in frequency and severity, especially in emotional excitement. Moderate amount of chlorosis. The muscles round the left eye and in front of the upper jaw chiefly affected. No pressure points. Otherwise healthy.

November 1867. Galvanic treatment: A stabile on the plexus anserinus and behind the ear. After 30 sittings great improvement, with some variations, and subsequently cure.

115. *Observation by Moritz Meyer. Clonic Facial Muscular Spasm.*—A solicitor, aged 30. Gradually developing right-sided facial spasm for some months, localised chiefly in the muscles in front of the ear and the orbicularis palpebrarum. Attacks frequent. Pressure on the small, tender projection over the transverse process of the 3rd or 4th cervical vertebra on the right side removed the spasm at once. Treatment consisted in the application of the A (10 elements) to these pressure points. Improvement after a few sittings; recovery almost complete after 37 sittings. Return of the spasm after inflammation of the lungs, completely cured after 23 more sittings.

116. *Personal Observation. Spasm of the Right Splenius Muscle.*—A woman, aged 43. Spasm came on 3 months ago, in consequence of great excitement, accompanied by rheumatic pains in the occiput and neck. Head always drawn towards the right side; sleep disturbed by spasm. No improvement from injections of morphia. More careful examination showed it was the right splenius muscle in which the spasm was situated. Came on more strongly on movement, less during repose; all employment interfered with; cessation now during sleep. No pressure points. Some anæmia, otherwise perfectly healthy. Galvanic treatment: A stabile on the right on the muscle and in the nape of the neck, then stabile transversely and obliquely through the head. Decided improvement after 4 weeks of treatment,

but no further progress. *Swelling faradic currents* then tried: decided improvement after 3 weeks; head quiet when in repose, in reading, and with easy manual labour; spasm in a slight degree only on walking. Discharged.

117. *Observation by E. Remak. Spasm of the Cervical Muscles.*—A sempstress, aged 52. For nearly 3 years the most intense spasms of the cervical muscles, increasing in severity (principally in the right accessorius, but affecting also the splenius, digastric, &c., and accompanied by spasmus nictitans and spasmodic rotatory movements of the eyeball). Had been treated 17 years before by Remak, senior, for the same affection with galvanisation of the right cervical transverse processes. Had remained perfectly well for 15 years. Another form of galvanic treatment tried recently without any result. Found this time also that anodic treatment of the right cervical transverse processes by means of a medium stabile current (5 to 17 ma.) was beneficial; temporary relief of the spasm at once, and gradually (after 84 sittings) a marked improvement.

118. *Observation by Moritz Meyer. Clonic Spasm of Individual Cervical Muscles.*—A lady, aged 26. For a long time spasmodic movement of the head towards the left and posteriorly, combined with crepitation and crackling in the neighbourhood of the lower cervical vertebræ and various spasmodic twitchings in the extremities. Examination showed abnormal tension of the posterior muscles in the upper region of the neck, with tenderness on pressure over the transverse processes of the middle cervical vertebræ, on the left side. Spasm almost constant and very troublesome. Treatment: *Stabile action of the A on the upper left side of the neck*, K on the submaxillary fossa, for 10 minutes, an assistant carefully steadying the head, which was bent forward. After 4 weeks head held without support in the normal position for a few seconds; not till after 175 sittings so great an advance in improvement that the patient could go to the baths. Afterwards cured.

119. *Observation by Erdmann. Rheumatic Torticollis.*—A straw-hat worker, suffering from rheumatic torticollis for 4 months; head turned to the right, forwards and downwards; chin near the right shoulder. Passive movements painful. *Faradic brushing of the neck*; immediate relief to the movements of the head for some hours. Removal of the affection in 10 sittings by this means and the direct faradic excitation of the left splenius muscle.

120. *Observation by M. Rosenthal. Rheumatic Torticollis.*—A maidservant, aged 30. Contraction of the right trapezius, in consequence of a thorough wetting; head inclined backwards and to

the right, chin towards the left. *Passage of a galvanic current through the muscle*; movements of the head easier at once. Cure after a second sitting.

121. *Observation by Moritz Meyer. Rheumatic Contraction of the Levator Anguli Scapulæ.*—A girl, aged 12. Contraction of the left lev. ang. scap., coming on during the night, from cold; belly of the muscle distinctly projecting. *A few reversals of the current through the muscle*; immediate relaxation of the tension. Complete cure after 2 more sittings.

122. *Personal Observation. Tussis Nervosa.*—A girl, aged 12. Spasmodic fits of coughing for 6 months, occurring every few seconds in the form of a hoarse, toneless cough, combined with slight twitching movements of the shoulders and the lips. Complaints of pain in the region of the larynx. Objectively everything normal. Patient suffered from migraine. *Faradisation of the larynx* for 2 days; disappearance of the pain in the throat; no alteration in the cough. Then galvanic treatment: stabile, transversely through the larynx. Rapid improvement; complete disappearance of the cough after 5 days. Patient returned home. Return of the cough after a few days. Came again under treatment 4 weeks later; again disappearance of cough after 4 days of galvanic treatment, which was continued a few weeks longer. Cure.

123. *Observation by Moritz Meyer. Singultus with Simultaneous Weakness of the Left Arm.*—A gymnastic teacher, aged 40, very nervous. In consequence of great exertion 16 years ago a feeling of weakness in the left arm, combined with a feeling of oppression on the left side of the thorax, and frequent hiccuping. Pressure on the spinous process of the seventh cervical vertebra induced pain and severe hiccup, recurring about 20 times in half a minute; pressure on the transverse processes of the third to the fifth cervical vertebræ painful. Immediate improvement after anodic treatment of these pressure points, and almost complete cure of the affection after 9 sittings.

124. *Personal Observation. Spasm of the Recti Abdominis and Latissimi Dorsi.*—A female factory hand, aged 24, very anæmic. Spasmodic twitching in the abdomen for 1¼ year, painless but increasing in frequency and severity, with intermissions of a day or longer. Examination showed isolated, short, and lightning-like twitchings in both recti abdominis, and, synchronous with this, a somewhat weaker twitching in both latissimi, and at intervals also in the pectoralis major. Pressure of variable duration to the abdomen excited the spasm. No signs of hysteria. Considerable improve-

ment on passing *stabile galvanic currents* from the spine to the epigastrium.

125. *Observation by Moritz Meyer. Tremor of the Right Arm.*—A boy, aged 14. For 2 years a gradually increasing trembling in the right arm. *Stabile galvanic current,* ascending, from the radial nerve to the plexus, and *labile galvanisation* of the extensors of the forearm. Decided improvement after 3 sittings; after 10, a quarter of an hour's writing without trembling. Cure after 19 sittings.

126. *Personal Observation. Clonic Spasm of the Lower Extremity, in consequence of Articular Neurosis*—An officer, aged 28, nervous. Struck on the left internal malleolus by a rebounding shot in the beginning of July 1866. Inflammation and swelling of the whole leg; permanent pain and tenderness in the left knee, which had suffered from traumatic inflammation 14 years before. Pain so great as to prevent walking and standing on the left leg. Subsequently twitching in the calf and thigh muscles, increased on bending the knee and interfering considerably with sleep. Condition on August 30, 1866: Left leg kept perfectly stiff; knee joint slightly swollen, excessively tender on pressure; lively fibrillary and clonic twitching in the calf and in the thigh, increased by touching the knee cap and by any attempt at flexion. Sensibility quite normal. Galvanic treatment: A stabile on the knee joint for 2 or 3 minutes, then descending stabile through the crural and the sciatic nerves, 3 to 4 minutes on each; later, in the same way, through the lower part of the spine. Hyperæsthesia of the knee less immediately after the 1st application, and sleep better. After the 4th application disappearance of the hyperæsthesia, and almost of the twitching; flexion of the knee easy. Walking possible on even ground without a stick. A long walk after the 14th application. Discharged cured after the 18th.

127. *Observation by R. Remak. Hemiplegic Contraction.*—A patient who had suffered for 2 years from hemiplegia with contraction. *Primary faradic current* passed through the affected flexors of the forearm; the hand immediately opened passively with ease, and the fingers straightened. In the same patient the contraction was relieved in a surprising manner by the passage of descending galvanic currents through the nerves of the contracted flexor muscles, with simultaneous increase of voluntary power over the paralysed muscles.

128. *Observation by R. Remak. Rheumatic Contraction.*—A female weaver, aged 49. Chronic articular rheumatism of the upper extremities for 17 years; contraction of the flexor muscles from the shoulder to the hand. Galvanic current through the muscles of the

right shoulder and the right upper arm for 6 minutes. Arm immediately raised higher than for 17 years. Continued improvement on the following day. The muscles of the forearm and hand treated in the same manner, with a similar result, and at a later period the left arm also.

129. *Observation by Bärwinkel. Contraction after Myelitis from Compression.*—A boy, aged 6. Paraplegia from caries of the vertebræ, paralysis and anæsthesia of the legs, greatly exaggerated reflexes, flexure contraction in the knee, extensive contraction in the foot. *Strong galvanic current* from the upper surface of the kyphosis to the sacrum (in either direction, but the ascending more effectual); immediate relaxation of the ankle joint while the current remains closed, and for a few moments longer. Knee and hip joint uninfluenced.

130. *Observation by Leloir. Hysterical Contraction.*—A woman, aged 22. Anæsthesia of the left hand and forearm, left ovarial hyperæsthesia and hysterical contraction of the left hand for 2 months. Cured in 11 days by the *permanent application of a weak galvanic current* of 5 to 10 elements, for 6 hours daily.

131. *Observation by Moritz Meyer. Reflex Contraction of the Quadratus Lumborum.*—A preacher, aged 33. Weakness in the left knee and ankle since February 1879, with swelling in the left gluteal and dorsal muscles. Gradual improvement, then aggravation, with flexion of the spine towards the right, necessitating a steel corset and a thick layer of cork in the right boot. The scoliosis of the lower dorsal and lumbar vertebral region apparently caused by very firm contraction of the left quadratus lumborum (in consequence of periostitis of the lumbar vertebræ?) No great result from the passage of a galvanic current through the muscle, but considerable and immediate improvement on placing one pole on the quadratus lumborum, the other on the sacro-lumbalis, and passing *reversals of a strong galvanic current* (40 to 50 elements). Striking improvement; disappearance of the scoliosis after 14 sittings and ability to take a 3-hours' walk.

In deciding upon the *electrotherapeutic methods* the removal of any accessible lesion which may be present in the nervous system must be thought of—that is, causal indications must be fulfilled. This will be done by the electric treatment of the organic diseases of the brain, spinal cord, or peripheral nerves which may be present, according to known methods. There is no doubt that something may often be effected by means of this procedure, which will be specially successful in the removal of many reflex irritations. It is only to be regretted that in so many cases such a causal disease cannot be proved with certainty.

You will generally have to employ the *direct antispastic action of the current*, and you will often be perplexed as to where the electrodes ought really to be applied in order to influence the specially diseased section—whether on the muscles themselves, on the peripheral motor nerves, on the spinal roots, on the spinal cord or brain as far as the cortex, or, finally, on quite distant parts, tender spots, sensory nerves, &c. Very often we are not in a position to decide this with any probability, and we are then obliged to seek the proper method and to effect cure by means of systematic experimentation on the different localities. This may be very elaborate and tedious, and it does not always succeed, as I could prove by many observations.

The various *methods of antispastic treatment* correspond pretty closely to those of the antineuralgic treatment; and I may, therefore, describe them very shortly. In order to induce the required modifying and katalytic action in the motor-nerve apparatus you will first employ the *galvanic current*; and here, as in neuralgia, the stabile action is to be preferred. You place the anode on the nerve trunk (or on the spinal cord, brain, or whatever point you wish to influence), beginning preferably with a very weak current, gradually increasing it by the smallest possible increment and after some time gradually diminishing it again in the same way. This stabile anodic treatment, for which, as a rule, only currents of moderate strength are to be recommended, proves useful in many cases. If it is unsuccessful you may try the kathode in the same way, as it may have other katalytic actions. Descending stabile currents passed through the motor nerves, to which R. Remak first ascribed distinct antispastic effects in contraction, act in the same way; still the ascending current seems sometimes to have been more effectual. He has also seen a similarly beneficial effect from the frequently repeated interruptions of a descending current passed through the nerve and muscle, especially in tonic reflex spasms. The fact discovered by Ranke, that galvanic currents of a certain strength, passed through the spinal cord, restrain the reflex spasms in strychnia poisoning, finds, perhaps, its analogy in the good results which Bärwinkel relates of diseased individuals (vide Obs. 129). The direction of the current appears to be immaterial for this purpose, if only its strength is sufficient.

But you may also attain antispastic effects with the *faradic current*; either by sending weak faradic currents with moist electrodes through the motor apparatus (perhaps also through the head and the spine), or strong faradic currents through the peripheral nerves and the muscles. Proceeding from the physiological fact that during the strong faradisation of muscles their extensibility increases, Remak has employed such currents for the removal of paralytic contraction, and with good results; the faradised muscles could be easily stretched, and remained flaccid and supple for some time—several hours. The best method of obtaining this effect is the application of 'swelling' faradic currents, which have been successfully employed by Frommhold, Benedikt, and myself.

It is not yet settled whether these procedures act by overstimulation and consequent exhaustion of the motor apparatus, by alteration of the tissue metamorphosis, or by the diminution of the irritability. Probably the already mentioned frequently repeated interruptions of the galvanic current, i.e. frequently repeated KC, may act in the same way; and perhaps also the frequently repeated reversals of the current in the region of the spasm, to which Benedikt ascribes a very special effect in many spasms, especially in convulsive tic, and which Moritz Meyer has recently recommended for contraction (vide Obs. 121 and 131).

A second manner of treating spasm is by the *removal of peripheral irritations* in the so called reflex spasms. Here the usual methods in neuralgia and other sensory irritative conditions may be employed; therefore here again chiefly stabile galvanic currents, &c., but applied to the sensory nerves and their expansions. To this place belongs also the electrical treatment of tender spots and of sympathetic tracts and ganglia, with which R. Remak was very successful, and which has also yielded some splendid results to other observers; but it is unfortunate that these tender spots are so rare and that they do not occur nearly so often as one would expect from Remak's descriptions. The stabile anodic treatment of these spots is first to be tried; sometimes their effect is exhausted after a time, and other points must be sought out.

Another occasionally successful plan consists in inducing inhibitory effects by means of very strong peripheral irritation. This may be accomplished either, as in neuralgia, by removing the sensory, reflex-exciting irritation, or by exercising an inhibitory effect directly on the motor stimulation by means of a strong irritation. The faradic brush or the moxa will answer this purpose, applied to various parts of the skin, either in the near neighbourhood of or distant from the affected motor nerves, over the spine, or in the epigastrium. In many cases it is useful to stimulate the tender points which may be present, either with the faradic brush or with the kathode stabile, if there are any whose irritation causes cessation of the spasm.

I may remark, finally, that in long-standing rheumatic and other contractions it has been attempted to improve the contraction, deformity, and mobility of the parts by means of faradic stimulation of the muscles antagonistic to those which are contracted. Duchenne and Erdmann have tried this with success in all sorts of contractions of the trunk muscles, and Brenner has recommended it for the cure of contraction after severe rheumatic facial paralysis. It is evident that this is not a real cure of the spasm, but only a kind of electro-orthopædics and gymnastics; still it is occasionally useful.

In paralytic contraction the treatment of the paralysed antagonistic muscles is often useful; for it is plain that the re-instalment and strengthening of the influence of the will on the paralysed muscles is the best means of combating the contraction resulting from the paralysis, just as, conversely, the removal of the contraction is useful for the improvement of the paralysis. But this also is only an indirect treatment of the spasm.

As you see, gentlemen, a great number of methods of electrical treatment are at our disposal against spasm, and it is often difficult to decide for one or the other of them. No certain indications have as yet been established, and very often the method on which we have counted most surely fails us, and we do not succeed until after other trials. Of course you will first choose your procedure according to established rules and the peculiarities of the case, but you must be prepared for failing and for being obliged to try all other methods in turn. As a general plan of treatment I would recommend you first to seek out causal diseases and the peculiar localisation of the affection, and to attack them first; afterwards the greatest care must be devoted to finding out reflex irritation and tender spots, for cases in which these are present are gradually more favourable for treatment. For the direct treatment I would advise beginning always with the mildest method, the stabile anodic treatment, and then, perhaps, proceeding to the descending stabile currents, to simple or 'swelling' faradic currents, then to the faradic brush, and finally to reversals of the current. Sometimes a method that has failed at first succeeds later; in obstinate cases, therefore, the different methods of application may even be tried several times. The skill and good fortune of electrotherapeutics have here a wide field of action.

The intensity and duration of the different applications are determined by the individual circumstances. It is always advisable to begin with weak currents and short sittings, but to advance gradually to stronger measures, and perhaps to repeat them several times a day. The duration of the whole treatment must often be very long, and you must not weary of it. When the spasm has been diminished to a few traces we ought, according to Remak, to discontinue the treatment and leave the full cure to nature. You must always be prepared for relapses, which come on very frequently and easily, even after long intermissions.

The *results* of electrical treatment in spasms are in the highest degree uncertain; it can hardly ever be predicted, or even expected with any degree of probability, that a cure will result. Sometimes the results are surprising and brilliant; at other times the obstinacy of the affection reduces doctor and patients to sheer despair. Even apparently slight cases, in otherwise healthy individuals, may defy electrical and all other treatment; and you must always be prepared for this in cases of spasm. We can hardly, therefore, lay down any general rules with regard to the prognosis of the electrical treatment; the rheumatic muscular contractures, and the spasms caused by cold, neuritis, trauma, and the like, are comparatively favourable, reflex spasms and those accompanied by distinct tender spots particularly so; the forms depending on severe neuropathic diathesis, frequently relapsing spasms, and spasms in organic diseases of the brain and spinal cord are very obstinate; while other more functional central spasmodic diseases warrant a more favourable prognosis.

In describing the *different forms of spasm* I may confine myself to mentioning a few individual peculiarities.

Spasm of the muscles of mastication (in the tonic form as trismus, in the clonic form as grinding or gnashing of teeth) is very rarely found by itself; it is more frequently an accompanying symptom of general forms of spasm. The isolated forms sometimes occur from direct disease of the motor portion of the fifth nerve, but more frequently in a reflex manner—in irritative conditions in the region of the fifth nerve, dental affections, disease of the articulation of the lower jaw, peripheral injuries, worms, &c. The electrical treatment must be directed to these points, but otherwise it presents no peculiarities and may be employed in the greatest possible variety of ways.

But *histrionic convulsion of the face, facial spasm, tic convulsif*, is observed most frequently, in all its varied forms —partial or diffused, tonic and clonic spasm, and occasionally also in the form of slight contraction (after facial paralysis). It may occur from very different causes, but the worst form is generally just that in which no cause at all can be ascertained, and in which the true, diffuse *tic convulsif* continues for years. Peripheral and central diseases are sometimes found to be the causes; and the recent investigations into 'cortical' forms of spasm have urged us to the supposition that part at least of the 'idiopathic' clonic facial spasm is to be referred to disease —probably imperceptible—of the cerebral cortex, in the region of the so called facial centre.

The electrical treatment of these spasms demands equal acuteness and patience from the physician; all the various methods may be tried here—must often be tried in turn—and will often be tried in vain: the stabile action of the anode with increasing and diminishing strength of current on the plexus anserinus or behind the ear on the trunk of the facial; transverse passage of the current through the mastoid processes (anode on the affected side); and stabile action of the anode on the opposite cranial region, in the neighbourhoood of the facial centre (bottom of ascending frontal convolution, fig. 29, p. 292). This last method, first recommended by me, has been employed with good results by O. Berger in different cases. The 'large head electrode' makes the best anode, applied to the well-moistened cranial region (K on the back or in the opposite hand) stabile, gradually increasing and diminishing, the strength of the current being medium and the duration 5 to 10 minutes (according to Berger). This writer has lately cured, in a surprisingly short time, a very severe case of double-sided facial spasm of reflex origin (in consequence of a blow in the region of the infra-orbital nerve), by means of stabile anodic treatment to the occiput (K being in the hand). This cure was probably effected by the action of the current on the morbidly excited reflex centre in the medulla, and this method, therefore, may be deserving of a trial. Later on you may try descending stabile currents in the separate nerve twigs, or frequently repeated KC or reversals of the current, to which Benedikt owed a number of good results. If you find tender spots (on the spine, on the face, inside the mouth, behind the ear, &c.) you must make them the subject of anodic treatment; and do not forget in severe cases to treat the several ganglia of the cervical sympathetic also, especially if they are tender on pressure. Remak ascribes an especial efficacy to this treatment and reminds us of the presence of the sympathic nerve twigs passing from the cervical ganglia to the large vessels of the head, especially that to the vertebral artery, which also contains an important vertebral branch from the first thoracic ganglion. This application possibly induces indirect katalytic effects.

But you may also employ faradic currents to the nerves, often with good effect; and also faradic currents transversely and longitudinally through the head or the cortical regions in question; and, finally, there remains the trial with the faradic brush, which you may apply to the skin of the nape of the neck, to the posterior auricular region, or to the tender spots which may be present.

Partial facial spasms, especially the common *blepharospasm*, may be treated in an exactly analogous manner. Anodic treatment on the closed eyelids and the region of the supra-orbital nerve is to be recommended in the first place, and then the seeking out and treatment of the tender points, which play so important a part in this very form, according to the splendid investigations of v. Gräfe and Remak; to which may be added galvanic treatment of the sympathetic and its several ganglia. For the rest, patience and perseverance are necessary before obtaining any results.

I shall only advert in passing to the treatment of *spasms of the tongue* and *ocular muscles*, which are very rare affections; you must treat them, as the cases come before you, according to general rules.

On the other hand *spasms in the muscles supplied by the accessorius* and *the other muscles of the neck* are not very rare; but they are always very troublesome to patients so affected. They present close analogies to true *tic convulsif* in several particulars, not least in the obstinacy of their nature, and ought, therefore, to be treated according to exactly the same rules and with the same methods. I include in this category spasms in the sternocleidomastoids, trapezius, splenii, rotatores capitis, levator anguli scapulæ, and the rest of the deep nape and neck muscles, whose symptomatology and diagnosis you must study in the handbooks of nervous pathology. The anodic treatment, recently recommended by E. Remak, of the nape, the spinal accessory nerves, and the cervical sympathetic deserves first to be tried. To this I now generally add the anodic treatment of the affected section of the opposite part of the cerebral cortex; and an action upon the medulla (transversely through the mastoid processes) may also be tried. If you find tender spots, as is often the case, these must first be attacked, and the other antispastic methods, before mentioned, may then be tried in turn. But these forms of spasm belong to the most obstinate and troublesome that can be imagined: I have seen frightful cases of the kind.

Tonic spasms are also very common in these muscles, frequently presenting themselves in their recent forms as rheumatic torticollis, and constituting a very favourable subject for electrical treatment (cf. Obs. 120 and 121). A few sittings are usually enough to remove the affection (anode stabile, reversals of the current, or powerful faradisation). But this is more difficult in the congenital forms or in those which have already passed into a condition of permanent contraction. In those cases every method is often tried in vain, and the utmost that can be attained is some amount of relief following the regular gymnastic and orthopædic faradisation of the antagonistic muscles.

The same is true of *spasms and contractions of the other muscles of the trunk*, in the back and abdomen, which may be observed in the most marvellous forms and combinations, and which generally present the greatest difficulties to clinical investigation and explanation. In these cases, also, electrotherapeutics is not very successful. Their treatment is to be carried out according to general rules, and it generally consists in a more or less systematic experimentation, with the most varied methods, on all the parts of the peripheral and central nervous system from which the spasm could possibly proceed. I need not enter more minutely into the matter

Spasms of the respiratory muscles, *inspiratory and expiratory spasms*, *singultus*, &c., ought to be mentioned here, as they occasionally fall into the domain of electrotherapeutics. These spasms, most frequent in hysterical individuals, affect either the diaphragm alone or the whole respiratory mechanism, or only inspiration or expiration alone, as in the different expiratory acts, coughing, sneezing, weeping, laughing, crying out, &c. All that can be said about them, beyond general remarks, will be something like the following: In *tonic spasm of the diaphragm*, an extremely rare affection, good results have sometimes been seen from strong faradic brushing of the skin in the region of the diaphragm—in the epigastrium—and also from faradisation or galvanisation of the phrenic nerves in the neck and nape. The same treatment may be employed in *clonic diaphragmatic spasm*, *singultus*, which sometimes becomes very obstinate and troublesome, and demands energetic treatment. I have seen brilliant results in such cases from the faradic brushing of the epigastrium, and others report the same from faradisation or galvanisation of the phrenic nerves. In many cases the anodic treatment of the nape of the neck, or the transverse passage of the current through the mastoid processes, may be of service, and also energetic stimulation of the expansion of the superior laryngeal nerve. Electric treatment is generally of very little use for the *complicated forms of respiratory spasm* (inspiratory and expiratory spasm, spasmodic sneezing, yawning, laughing, weeping, coughing, &c.) The cases in which most may be accomplished are those in which the causal indication (hysteria, peripheral irritation, tender ovaries, &c.) may happen to require electrotherapeutical interference. You may adopt the same methods of procedure for these spasms as for spasm of the diaphragm; and you will be most likely to succeed with strong farado-cutaneous irritation. I have seen faradisation and galvanisation of the larynx prove useful in spasmodic cough, and Fritsche has found the various galvanic applications of service in spastic aphonia.

Spasms in the muscles of the upper extremities are met with every day. Generally they are symptoms of more diffuse forms of spasm and other neuroses (chorea, tetanus, hysteria, paralysis agitans, epilepsy, &c.), in which connection they will occupy us later when we treat of those affections; or they are symptoms and consequences of severe local central diseases, such as hemiplegic contractions, post-hemiplegic chorea and athetosis, cortical partial epilepsy, contraction in spinal affections, &c., when they will frequently require no other treatment than that of the fundamental affection. Sometimes, however, we have to do with spasms which originate locally in the upper extremity, from neuritis of individual nerves, joint affections, neuralgias, &c. There are, then, a great number of forms of spasm to be observed in the upper extremity, and their treatment is, therefore, sometimes very complicated.

First of all, of course, the fundamental affection has to be treated, and then the various antispastic methods, already mentioned, may be applied to the nerves and muscles of the arm, to the nape and the neck, to any tender spots on the brachial plexus or on the spine, &c., from a further description of which you may certainly excuse me. The anodic treatment of the nape and of the plexus stands in the foreground here also. For idiopathic or secondary contractions you may employ the various methods which I have already described (descending stabile galvanic currents, frequently interrupted galvanic currents or reversals of the current, strong faradisation with simultaneous extension of the muscles, &c.) For the partial, clonic spasms in cortical lesions you may try the treatment of the cortical centres.

For *spasms in the lower extremities* the same holds good, *mutatis mutandis*, as for the upper. Most frequently they are symptoms of widespread general forms of spasm, or of central disease, especially spinal disease. Still purely peripheral spasms—reflex spasms from articular affections, neuralgias, foreign bodies, &c.—occasionally occur; and very frequently also paralytic and hysterical contractions, and the so called cramps, especially in the muscles of the calf.

The choice of methods of treatment must be made according to general rules; you will most frequently have to treat the spinal affection, and to determine the method of application according to the special case. Further details are unnecessary.

VII. ANÆSTHESIA.

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LECTURE XXIX.

Meaning and Pathogenesis of Anæsthesia—Electrical Examination—Objects of Electrotherapeutics—Cases—Electrical Methods of Treatment—Causal Treatment—Direct Treatment of Anæsthesia—Methods with the Faradic and Galvanic Current — Removal of Secondary Trophic Disturbances—Results—Various Forms—Anæsthesia of the Trigeminus, of the Pharynx and Larynx—Vasomotor Anæsthesia — Hysterical Anæsthesia — Tabetic Anæsthesia.

JUST as spasms and their treatment present certain analogies with neuralgia, so anæsthesia stands in the closest relation to paralysis. It owes its origin to similar, very often to exactly the same lesions, and its electrical treatment is directed according to the same rules, making use of the same methods as that of paralysis. But the result of the anatomical and physiological relations of the centripetal nerve tracks is that we have to do with comparatively simpler and much less complicated therapeutical problems here than in paralysis, so that the methods of treatment also are correspondingly simpler and uniform. I may be allowed, therefore, a comparatively short description.

By the term *anæsthesia* we understand the diminution or abolition of the sensations conveyed to the seat of consciousness by means of the sensory nerves and the nerves of special sense, with reference chiefly to the cutaneous and muscular anæsthesiæ. (The sensory and visceral anæsthesiæ will be described later, as occasion arises.) This functional disturbance may be occasioned either by diminution of the irritability of the peripheral or central terminal sensory apparatus, or by an inhibition and interruption of the conductive processes in the sensory nerve tracks (conductive anæsthesia). These latter are certainly the most frequent and important forms of anæsthesia; and they also form, almost to the exclusion of the others, the subjects of electrical treatment.

The existence of an anæsthesia from *exclusive* disease of the peripheral sensory terminal apparatus (in the skin, tendons, muscles, joints, &c.) appears not yet sufficiently established, for an implication of the nearest and finest sensory tracks is generally included, as in the forms of anæsthesia, generally only slight in degree, occasioned by cold (ether spray), heat, caustics (washing-lye, carbolic acid, &c.), ischæmia (vasomotor neurosis,) &c.

Anæsthesia from disease of the central receptive apparatus exclusively is just as little established. We surmise, indeed, that this apparatus is situated in certain sections of the cerebral cortex (sensory cortical regions), and we may easily conceive that a more or less isolated disease of this portion may occur, but it will be difficult to determine how far the nearest sensory tracks in the brain are affected in the diseases concerned (cortical encephalitis, softening, hæmorrhage, meningitis, intoxication, &c.) This has, however, no special importance for electrotherapeutics, if only the seat of the disease in the brain or in the cortical substance can be definitely proved.

The *anæsthesiæ occurring from hindrance to the sensory conduction* in any part of its course are certainly the most numerous and frequent, and they are much more obvious in their pathogenesis. These hindrances to conduction may, just as in paralysis, be placed within the *peripheral* tracks by means of the most varied lesions; or they may occur within the *spinal* conduction, by means of the various spinal diseases; or, finally, they may be caused by disease of the *cerebral* tracks, from hæmorrhage, softening, tumours, sclerosis, &c. Certainly these conduction tracks and their position in the spinal cord (posterior fibres, grey posterior columns?) and in the brain (crura cerebri, posterior part of the internal capsule, corona radiata) are very imperfectly known. It is possible, and even very probable, that in all the places mentioned anæsthesia may have been caused by so called imperceptible lesions (e.g. hysteria, poisoning, syphilis, &c.), but in most cases of the kind we have no accurate idea in what exact spot this imperceptible lesion occurs in individual cases.

I shall not touch upon the symptomatology of anæsthesia further than to point out to you how you may, from its extent (circumscribed in the region of one or another nerve, in a paraplegic, hemiparaplegic, or, finally, hemiplegic form), obtain data for determining the seat of the lesion, the knowledge of which must, of course, form the foundation of your treatment; and how you may, further, draw conclusions from the partial or total paralysis of sensation, its more or less complete abolition, the presence, nature, and extent of paræsthesia in the same direction, as well as from the presence or absence of motor, vasomotor, trophic, and special-sense disturbances, neuralgic difficulties, &c.

Electrical examination can contribute comparatively little to the clearing up of the diagnosis in this direction, although it is sometimes not without value. I have told you before that quantitative or qualitative changes in the electrical irritability of the nerve trunks, which are of such diagnostic value in paralysis of the motor nerves, are unknown in anæsthesia; for in the same way as we cannot recognise irritative changes in the *central* portion of the motor nerve in paralysis because conduction to the muscles is interrupted, so we cannot distinguish those changes in the *peripheral* part of the nerve in anæsthesia because the passage to the brain is interrupted. This test, therefore, is only practicable in incomplete anæsthesia. On the other hand you will remember that we may employ the electrical current for finding out and defining the functional disturbances of the sensory apparatus itself, in regard to which I refer you to what was said in Lecture XI., p. 225. In the farado-cutaneous sensibility test we possess a splendid means of detecting more especially the finer differences in symmetrical parts, of limiting and localising them, and of detecting analgesia.

Now, gentlemen, for an affection of the sensory nerves, which makes the skin and other organs more or less insensible to stimulation, strong cutaneous irritation has always been employed as the chief remedy, and as in the electric current we possess the most eligible and most convenient means of producing cutaneous irritation of any desired strength up to the most intense, and of doing this without any permanent change or serious disturbance of the skin (which is unavoidable in urtication, vesication, and the use of ferrum candens), it is sufficiently obvious that we may apply it for the relief of anæsthesia. It is, indeed, the sovereign remedy for all forms of anæsthesia in all parts of the body, in so far of course as we have to do with curable anæsthesia at all.

The problems which fall to the lot of electrotherapeutics with regard to anæsthesia may be enumerated in a few words, exactly as in the case of paralysis. We may require the removal of the disease which prevents conduction, the increase of the irritability of the receptive organs, the removal of hindrances in the sensory conduction itself, or, finally, the removal of secondary nutritive disturbances (of a finer or grosser nature) which may be present, and which may stand in the way of the complete conductibility of the sensory apparatus.

I need not repeat in detail the description of the various actions of the current which we must regard as being at our disposal for the fulfilment of these ends ; I need only say shortly that they are the katalytic, vasomotor, modifying, and, most particularly, the stimulating actions.

And, indeed, we owe a number of very satisfactory results in anæsthesia to these actions—results which are effected, perhaps, with even greater ease and regularity than in paralysis, as the sensory tracks generally prove more resistant to all kinds of lesions than the motor. A few examples may serve to illustrate this, as a number have already been given in formerly mentioned cases of favourable action of the current on anæsthesia (Obs. 10, 12, 18, 25, 26, 31, 37, 45, 65, 66, 73, 74, 78, and 81).

132. *Personal Observation. Anæsthesia in the Region of the Left Trigeminus.*—A cook, aged 48. Taken ill in August 1870 with numbness and formication in the left side of the face. Never any pain; frequent dizziness; eye red and very watery; recently also numbness of the soft palate and the tongue, and diminution of taste on the left half of the tongue. Otherwise healthy. Condition on December 13, 1870: Diminished sensibility on the whole left side of the face, tongue, and soft palate; no complete anæsthesia; left eye red and watery, with a superficial corneal ulcer. Taste diminished on the left anterior part of the tongue. No abnormality of the muscles of mastication. Facial region normal; hearing good. Galvanic treatment: 6 to 8 cells (Stöhrer) transversely through the temples and mastoid processes; 8 cells with K labile over the whole skin of the face. After the 3rd sitting decided improvement: sensibility better on forehead and cheeks; hyperæmia of conjunctiva disappeared. After the 8th application improvement permanent; sensibility better, numbness in mouth less. After the 15th sitting improvement of taste on the left half of the tongue. Patient ceased to attend.

133. *Personal Observation. Traumatic Paralysis and Anæsthesia of the Left Ulnar and Median Nerves.*—A labourer, aged 21. Severe dislocation of the elbow in February 1872; not treated for 16 days, and then bandaged badly. In the middle of November 1872 complete paralysis of the whole ulnar and median regions in the hand (small muscles of the hand), with great atrophy and complete RD. Sensibility completely absent in the region of the nerves mentioned, on the dorsal and palmar surfaces; on the dorsal surface normal sensibility present in the radial region alone. Excentric sensation induced in the hand from the elbow by means of the faradic current, in the ulnar and median nerves, ceasing suddenly about 2 inches above the wrist. Treatment: K labile with reversals of the current to the median and ulnar nerves and their areas of distribution. November 23. Improvement of the sensibility in the back and palm of the hand. December 5. Advance of improvement; a little sensibility in the tip of the little finger. December 15. Sensibility present almost everywhere, although still in a weakened degree. January 28, 1873. Sensibility almost entirely re-established, motility still unaffected. No subsequent change on further treatment.

134. *Observation by Moritz Meyer. Anæsthesia of the Ulnar Nerve.*—A peasant, aged 38. Six weeks ago severe 'sleep paralysis' of the ulnar and median cutaneous nerves. The ulnar side of the forearm, as well as the ulnar region of the hand, completely anæsthetic; the muscles supplied by the ulnar paralysed and atrophic. Faradic treatment of the skin and muscles. After 5 sittings return of sensibility, although weakened; complete cure after 12 sittings.

135. *Observation by Vulpian. Hæmorrhagic Lesion of the Right Cerebral Hemisphere. Hemianæsthesia of the Left Side, &c.*—A day labourer, aged 45. Stroke 14 days before, and, in consequence, weakness of the left side and loss of sight in the left eye. The whole left side of the body completely anæsthetic to all irritation. Taste abolished on the left side and sight much diminished; hearing normal. Anæsthesia also of the left half of the palate; muscular sensibility also diminished on the left side. Treatment: Application of the faradic brush to a circumscribed portion of the skin on the dorsal side of the left forearm. After 3 days sensibility returned to the hand and to the anterior surface of the thigh. Finger-tips and internal surface of the thigh sensitive after 8 days. Gradual advance of improvement. Dorsal and inner surface of the forearm sensitive after 4 weeks, as also the upper arm; excentric sensation on irritation of the ulnar nerve in the arm lessened; progress to almost complete cure.

136. *Observation by Grasset. Right Cerebral Hemianæsthesia.*—A male patient, presenting a complete picture of right cerebral hemianæsthesia, with hemiparesis and with diminution of taste and of acuteness of sight on the right side. Trembling on intentional movement in the left upper extremity. Treatment: Farado-cutaneous brushing on the outer side of the right forearm with the strongest current; at first no sensation, gradually an increasingly severe prickling, and from that moment return of sensibility to the whole right side, vision of the right eye being almost normal. 15 minutes later diminution of sensibility, but on the following day decided improvement. Similar trials with faradisation on the right thigh and also on the left gave exactly similar results.

137. *Observation by Leloir (Vulpian). Right Hysterical Hemianæsthesia.*—A girl of 13½. Attacked with severe fits of hystero-epilepsy at the time of the first menses. Six months later complete anæsthesia and analgesia of the whole right side of the body; ovarian tenderness on the left side; smell and taste very much and hearing moderately diminished on the right side; sight unaffected. A single local faradic brushing of the right forearm, lasting for 4 minutes, induced complete

cure of the anæsthesia and considerable improvement in other respects. Result permanent.

In the choice of *electric methods of treatment* for anæsthesia we have first to consider, as in paralysis, the removal of the anæsthetising lesion, i.e. the discovery and treatment of the focus of disease itself, the neuritis, compression, hæmorrhage, myelitis, tabes, cerebral affection, &c., which may be present, and also the imperceptible disturbances of nutrition, if their exact seat can be discovered, or the general neurosis which occasionally makes itself known by anæsthesia. This is to be done according to principles, some of which you know already, while others will be discussed in subsequent lectures.

This part of the electrical treatment is the principal thing in many cases, and is often sufficient for the removal of the anæsthesia, and if this indication has to be fulfilled at all it is most reasonable to fulfil it first.

But this is by no means always practicable, partly because we do not know the situation and nature of the lesion, and partly because it may not be accessible to electrical treatment at all, but may require some other kind. In not a few cases, however, this may not be sufficient by itself; the regeneration may, for example, have advanced so far that the passage of the current is certainly *possible*, but is not carried out in reality, and a strong shock may first be necessary, in order to restore the conductivity. Direct treatment is also needed for the removal of the anæsthesia, or at least for its *rapid* removal.

This direct treatment aims at an increase or a reinstating of the irritability of the peripheral (now and then also of the central) terminal apparatus, or at a restoration of the conductibility of the centripetal tracks. The first is certainly of subordinate importance, and seldom comes into question, unless it coincides with the fulfilment of the causal indication; but the latter—the restoration of conduction—is the principal thing and is what must be striven after in most cases.

The methods, however, for the attainment of both these ends are almost the same. They consist essentially in a sufficiently strong, frequently repeated stimulation of the sensory terminal apparatus and conductive tracks, in order to remove, by means of a strong irritation, the hindrances in the sensory track, and thereby to compel the restoration of the conduction, and so at length, by means of the frequent employment of this conduction by artificial irritative processes, to make the track gradually more easily accessible for weaker irritations, i.e. for the natural stimuli.

We find ourselves in a much more favourable situation for the realising of this view in anæsthesia than in paralysis. For the latter we formulated the postulate that the electric irritation must be brought centrally to the seat of lesion, in order to accomplish the action desired; and you have seen that we are not always able to do this, but that we must often attain our end in a roundabout way, and that a very uncertain one (reflex irritation). This is not the case in anæsthesia; here the irritation must be applied peripherally to the seat of lesion, and the peripheral terminal apparatus and peripheral sensory nerve-tracks are always at our disposal for this purpose. From this results very simply the method for the direct treatment of anæsthesia—peripheral irritation of the skin, the sensory nerve-trunks, and, if necessary, other deep-lying parts also, if possible with such strong currents that a sensation, even if only faint, is perceived. If this does not produce a result at once it may, perhaps, do so later and gradually, as the stimulation waves, breaking repeatedly against the obstruction, clear it gradually out of the way, and make the track free, first for strong and subsequently for weaker stimuli. For this purpose the strongest stimulus is applied at first, and weaker ones may be chosen as the power of conduction increases.

With the *galvanic current* the employment of the K, stabile and labile on the skin and the nerve trunks, is the most suitable, as also the employment of KC and reversals, for the stronger stimulation. The metallic brush, connected with the kathode, caused very great irritation; but with it very strong currents must be employed, and caution is necessary lest the brush should remain too long on one part of the skin, which would quickly cause an eschar.

But the *faradic current* is generally preferred for this purpose, as it, by means of the brush or the moxa, with a rapidly vibrating secondary current, causes a very great irritation of the skin, which may be graduated easily and accurately every moment, without ever leaving evil consequences behind it. Farado-cutaneous brushing, then, is the principal method, the skin being made rather dry beforehand by means of powdering. But you may also stimulate the nerve trunks themselves with moist electrodes, or let stimulating currents act on joints, muscles, mucous membranes, and other deep-lying parts. The current may be chosen so strong at first that a slight sensation is felt; this generally increases very quickly, so that the coil must be pushed back; and with increasing improvement weaker and weaker currents will be sufficient. In particularly obstinate cases you may employ farado-galvanic brushing.

With this treatment of anæsthesia we sometimes find, to our surprise, that not only the directly stimulated cutaneous regions and nerve trunks recover their sensibility, but that neighbouring and even distant cutaneous regions are relieved from anæsthesia temporarily or permanently—that, indeed, simultaneous anæsthesiæ of mucous membranes and joints, and even of organs of special sense, have been made to disappear by simple local faradisation of a circumscribed portion of skin. In cerebral hemianæsthesia, occasioned by organic lesions or imperceptible changes, and no less in other forms, especially in hysterical hemianæsthesia, the brushing of a small portion of skin is often sufficient to restore the sensibility entirely to the whole half of the body and even further. This fact, of which Moritz Meyer brings forward a good example in his textbook (3rd edition, p. 288), has recently been specially emphasised by Vulpian. He found that the faradic brushing of a small portion of skin on the upper extremity (external surface of the forearm), which was carried out daily for 8 or 10 minutes with very strong currents, had this beneficial action, often more beneficial than the faradisation of the whole of the anæsthetic portion of skin, and he prefers this localisation of the exciting action; but Grasset's observation shows that a similar effect may be produced from other portions of the anæsthetic half of the body, and even from the healthy side; and Rumpf employs preferably, also with good result, the faradic brushing of larger cutaneous surfaces. These facts probably stand in a certain relation to the metalloscopic phenomena in hysterical hemianæsthesia, and are equally obscure and enigmatical. We do not yet know whether we have to do with central radiations of peripheral irritative processes or perhaps with reflex katalytic actions, such as we have had to consider for the similar mode of treatment of paralysis; but in any case this method deserves further trial and more widespread employment in suitable cases.

Finally, in many cases the problem may still remain of removing secondary trophic disturbances in the sensory nerves, either finer nutritive disturbances, occasioned by want of use, or degenerative atrophy, from separation from the trophic centres, just as we have seen it in paralysis. The trophic centres for the peripheral sensory tracks lie in the spinal ganglia. This indication, then, occurs, in the first place, in peripheral anæsthesia, and must be fulfilled in exactly the same way as in paralysis (vide p. 436); the conditions, however, are much more favourable for the sensory nerves, in so far as they are likely to be regenerated more quickly than the motor, and, consequently, to resume their functions sooner. We have already seen how important this is in the treatment of paralysis. But secondary degenerations also occur in spinal anæsthesia; and the trophic centres for a part of the tracks here implicated appear also to lie in the spinal ganglia, their failure causing the secondary ascending degeneration of the posterior columns. But it is very questionable whether the electrical treatment of these, in cases of spinal anæsthesia, is at all useful or necessary.

The *results* of this treatment of anæsthesia are extremely varied, and are, of course, essentially determined by the nature of the fundamental lesion. It follows from this that a great number of cases are simply incurable. But in the curable cases great differences are also apparent; sometimes recovery follows rapidly, in a magical manner, in a few minutes or after a small number of sittings; or improvement appears at once, but only temporarily, the anæsthesia reappearing after a few hours or days, and the cure being accomplished gradually. This is observed particularly in the various hysterical and rheumatic anæsthesias, anæsthesia from slight compression, &c., while in other cases improvement comes on very slowly, as in traumatic paralysis, neuritis, tabes, and other spinal affections.

I have not many particulars to add about the several forms of anæsthesia.

Anæsthesia of the trigeminus is among the most important, and requires careful and far-sighted treatment—the galvanic current to the trunk and branches of the trigeminus, with K labile, or faradic brushing of the skin of the face and the mucous membrane of the mouth and tongue. The electric current appears also to have a good effect on the accompanying conjunctival hyperæmia.

Anæsthesia of the pharynx and the orifice of the larynx is very frequent after diphtheria, and requires special attention on account of the great danger of food pneumonia. It is to be treated according to the analogy of diphtheritic paralysis—intrapharyngeal and percutaneous application of faradic or galvanic currents, especially to the region of the superior laryngeal nerve. Jurasz recommends the alternation of both kinds of current.

In *vasomotor anæsthesia* the application to the vasomotors of means which will dilate the vessels is of course required (vide the following lecture), and also the direct treatment of the anæsthetic skin with strongly stimulating and rubefacient applications (A stabile, K labile, faradic brush). It generally yields rapidly to treatment.

In *hysterical anæsthesia and hemianæsthesia*, besides the peripheral employment of cutaneous faradisation, the treatment of the central organs must be attended to; and the treatment of ovarian tenderness or tender points which may be present is not to be forgotten. Vulpian's method should be tried here.

For *tabetic anæsthesia and analgesia* the treatment of the spinal cord itself is indicated in the first place, and it alone is often successful. But very good results have also been obtained by the peripheral application of the faradic brush (Moritz Meyer and recently Rumpf).

For *anæsthesia combined with paralysis*, affecting various parts of the body, besides the peripheral treatment of the anæsthesia, means suitable for the paralysis are also to be recommended.

I will make some observations later on anæsthesia of the mucous membrane of the bladder and rectum, urethra, genital organs, deficient sensual feelings, &c.

VIII. *DISEASES OF THE CERVICAL SYMPATHETIC. VASOMOTOR, TROPHIC, AND ALLIED NEUROSES.*

Literature.—Eulenburg and Guttmann: 'Pathologie des Sympathicus.' Berlin, 1873.—A. Eulenburg: 'Lehrbuch. d. Nervenkrankheiten,' 2nd edit. 1878.—'V. Ziemssen's Handb.,' xii. 2, 2nd edit. 1877.—Seeligmüller: 'Lehrb. d. Krankh. d. periph. Nerv. u. d. Sympath.' Brunswick, 1882.—'Ein Fall von acuter traumat. Reizung d. Halssympathicus,' *Arch. f. Psych. u. Nerv.*, v. p. 834, 1875.—'Zur Pathologie d. Sympath.,' *Deutsch. Arch. f. klin. Med.*, xx. p. 101, 1877.—Otto: 'Beitr. z. Pathol. d. Sympath.,' ibid. xi. p. 609, 1873.—Brunner: 'Z. Casuistik. d. Pathol. d. Sympath.,' *Petersb. med. Zeitschr.*, new series, ii. p. 260, 1871.—Mor. Meyer: 'Therap. Erfolge d. Galvanis. d. Sympath.,' *Berl. klin. Woch.*, 1870, No. 22.—Nothnagel: 'Zur Lehre von den vasomotor. Neurosen,' *Deutsch. Arch. f. klin. Med.*, ii. p. 173, 1867.—A. Lustig: 'Zur Lehre von den vasomotorischen Neurosen.' Diss. Breslau, 1875.—Seeligmüller: 'Hydrops articulorum intermittens,' *Deutsch. med. Woch.*, 1880, Nos. 5 and 6.—Rumpf: 'Ueber Reflexe,' ibid. 1880, No. 29.—Moncorvo and Silva Araujo: 'De l'Emploi de l'Electricité dans le Traitement de l'Eléphancie,' *Journ. d. Thérap.*, 1882, No. 1.—F. A. Hoffmann: 'Faradis. gegen Frostbeulen,' *Berl. klin. Woch.*, 1883, No. 2, p. 28.—Fr. Fieber: 'Zur galv. Behandlung d. Sclerodermie,' *Wien. med. Woch.*, 1870, No. 55.—Armaingaud: 'Note sur un Cas de Sclérodermie: Application des Cour. Continus, suivie de succès,' *Union Médic.*, 1878, No. 132.—Schwimmer: 'Die neuropathisch. Dermatosen.' Vienna and Leipzig, 1883.

LECTURE XXX.

Diseases of the Cervical Sympathetic—Their Occurrence and Symptoms—Irritation and Paralysis—Case—Methods of Electric Treatment—Vasomotor Neuroses—Cutaneous Angioneuroses—Symptoms in Spasm and Paralysis of the Vasomotor Nerves—Case—Methods of Electric Treatment for Vasomotor Spasm and Paralysis—Hydrops Articulorum Intermittens—Vasomotoro-Trophic Neurosis of the Skin—Anomalies of Secretion of Sweat—Hemiatrophia Facialis Progressiva—Probable Seat—Methods of Electrical Treatment—Scleroderma—Methods of Treatment.

Although I shall not omit a short description of electrotherapeutics in diseases of the cervical sympathetic, this will only refer to the comparatively surely established diseases of the nerve trunk itself or of its nearest origin in the cervical cord; I do not by any means intend to enter upon a number of diseases of very different nature which it has been the custom for some time to refer to the cervical sympathetic. I am certainly not of the opinion that migraine, Basedow's disease, progressive facial hemiatrophia, or even progressive muscular atrophy may be, with any probability, referred to the sympathetic, and, so far as I can see, most neuropathologists are inclining more and more to this opinion. And although we have not recently made much progress in the localisation of this and other diseases, still we have become somewhat more cautious in the uncritical acceptance of every new physiological fact in human pathology, often not accurate enough and still less often really explained. It is well known that we have sinned very much ir this respect with regard to the sympathetic.

The cervical sympathetic behaves like every other peripheral nerve with regard to morbid influences, and its diseases fall, therefore, under the same category as the lesions of other nerves. Such diseases are, certainly, very rare occurrences, and isolated lesions of the sympathetic, especially, belong to the category of pathological curiosities. They have such a peculiar and characteristic set of symptoms, and are of so much importance on account of the manifold relations of the sympathetic to all parts of the central nervous system, to the organs of special sense, and to certain vegetative organs, that a special description of them may certainly appear to be justified, although we may regard with the greatest scepticism the idea of the secret and magical relations of the cervical sympathetic to all other neuroses.

Diseases of the sympathetic may be induced by inflammation, rheumatic influences, injury, compression, &c.; diseases in the cervical cord and in the medulla may cause similar appearances; and imperceptible lesions also (as in hysteria, neurasthenia) seem sometimes to occur. These affections generally appear under two forms, sympathetic irritation and sympathetic paralysis; both disturbances may exist alongside of each other, irritation predominating in one part of the fibres and paralysis in another, or they may succeed each other in the course of the disease. The collection of symptoms resulting from this is sufficiently characteristic, but it generally requires very accurate examination, as the oculo-pupillary and vasomotor symptoms, with which we have chiefly to do, are often very little marked, the latter especially appearing to retreat into the background on long continuance of the disease.

The *symptoms of sympathetic irritation* (cf. the observation by Seeligmüller) consist in paleness and coldness of the corresponding half of the head and face, hardness and tension of the temporal arteries, dilatation of the pupils (with diminished reaction to light or movements of accommodation) with moderate protrusion of the eyeball and a slight widening of the interpalpebral space; diminution of secretion of sweat, &c.

The *symptoms of sympathetic paralysis*, on the other hand, show themselves in increase of temperature and greater redness of the face and head on the same side, also of the neck and nape, subjunctive heat and paræsthesia, dilatation and strong pulsation of the arteries, hyperæmia of the conjunctiva, cephalalgia, vertigo, swimming of the eyes; further, contraction of the pupils with retained reaction to light and movements of accommodation, slight contraction of the interpalpebral space, some retraction of the eyeball, increased secretion of tears and sweat, &c.

Electrical examination cannot help in clearing up the diagnosis, as we cannot induce certain stimulation of the sympathetic; still in such cases we can occasionally influence the morbid disturbances by the employment of the electric current, and thereby obtain data for the choice of the therapeutic methods.

There are very few useful examples of sympathetic disease —useful, that is, for our electrotherapeutical purposes.

138. *Observation by Otto. Paralysis of the Cervical Sympathetic.* —Frau E., never seriously ill, was seized suddenly, in the spring of 1870, with vomiting, pain in the head, and vertigo, with diminution of sight. After 14 days intermission of the symptoms, but great redness of the left half of the face, neck, and nape; later on difficulty of speech, loss of memory, occasional feeling of burning heat in the head, with vertigo and increased redness of the parts mentioned. These attacks increased by every psychical emotion. Combined with this, absolute loss of sleep, great depression, and permanent internal excitement. Frequent secretion of sweat over the reddened parts. Not much altera-

tion in this condition of things after a year and a half; erythematous blush specially noticeable, diffused over the whole left side of the face, neck, and nape, and extending downwards in the form of closely placed, irregular, and very red spots, diminishing in number, as far as the waist. Cervical sympathetic nowhere tender on pressure. *Galvanisation of the sympathetic* with K; immediately after 3 minutes' duration of the treatment disappearance of the vertigo. Sleep on the following night peaceful and unbroken. Complete freedom from vertigo after 10 sittings, and almost complete disappearance of the erythema after fading during the passage of the current in the first sitting. Improvement in sight, speech, and spirits. Cure after 18 sittings, remaining permanent.

The electrical treatment in these diseases is carried out, in general, just as in the lesions of the peripheral nerves. If the seat of lesion is to be found in the cervical sympathetic itself it is to be treated according to general rules; but if there is ground for believing that the real seat of the disease is to be found in the cervical cord, then it must be taken in hand in the usual way.

If such treatment is not possible, if no local lesion is evident, or if it does not fall within the province of electrotherapeutical operations, the methods of application to be chosen must be selected according to the quality of the chief symptoms, especially of the vasomotor disturbances, which may be prominent, as I shall explain more fully later on. Here there is only this to be said, that in symptoms of sympathetic irritation you must avail yourself exclusively of the galvanic current, and it seems from experience that the stabile anodic treatment of the sympathetic is the most suitable. A 'medium' or perhaps a suitably shaped elongated electrode is applied directly to the cord at the extreme limit, or to its principal ganglion (K on the back or an indifferent spot), and a tolerably strong current passed through stabile, for some minutes, until an effect is perceived on the vessels or on the pupil.

In distinct sympathetic paralysis, on the other hand, a slight and short action of the kathode seems to be indicated, with weak currents, frequent interruptions, and repeated KC, perhaps also with some reversals, but with short sittings (1 to

2 minutes), as otherwise an opposite effect is easily induced. Moderate faradisation of the nerve may also be tried.

It will generally be useful—in paralysis in the cervical sympathetic almost always—to add a treatment of the centres in the cervical cord in the same sense, in the one case the anode in a stabile, penetrating manner, in the other a moderate stabile and also labile action of the kathode.

In the same way it may be indicated in some cases to add peripheral treatment as a means of support, by treating the skin of the face and its vessels with the anode or kathode, stabile or labile, or by applying the faradic brush, the last-mentioned in order to produce reflex relaxation and redness of the skin in marked spasm of the vessels.

All that is left to be said about sympathetic diseases has been already treated in 'visceral neuralgias.'

We very frequently meet with *vasomotor disturbances* in neuropathology. You know that peripheral nervous affections (neuralgia, anæsthesia, paralysis), as well as spinal and cerebral diseases, are often accompanied by such disturbances; and they require, therefore, no special treatment as a rule. But occasionally they do occur in a more independent manner, as affections in which irritative or paralytic conditions of the vasomotor nerves, and corresponding changes in the diameter of the vessels and in the circulation, are primary and essential. They may set up a number of changes in sensibility, motility, cardiac action, cerebral function, &c. These, then, are called *vasomotor neuroses*. They may play a much greater part in the pathology of many internal organs than we yet *know of*, though certainly enough has been *imagined* with regard to them. Cutaneous vasomotor neuroses, however, especially those in the area of distribution of the cervical sympathetic, are somewhat more definitely known and much easier to observe, while we are still in the dark as to the vasomotor neuroses of the internal organs.

These *cutaneous angioneuroses*, as they are now technically called, will occupy us here for a moment. They occur in only two forms, but in very varying localisation, sometimes more diffused, sometimes localised on definite nerve regions. The extremities, especially the upper, are most frequently the seat of these neuroses, then the face and neck—those parts which normally display the greatest variety of vasomotor appearances, the greatest mobility of the vascular muscular system.

Spasm of the vasomotor nerves (cutaneous angiospasm) appears as contraction of the vessels, with paleness and coldness of the skin, which sometimes, especially in the fingers, looks chalky white and corpse-like (dying of the fingers), or, when it is long-continued, livid and cyanotic. Spasm of the small cutaneous muscles is generally combined with it (cutis anserina), and as sequelæ may be observed itching, pain, deadening of sensibility, awkwardness in the finer movements, &c., and, if the disturbance is extensive, alterations in the heart's action, going on to vasomotor angina pectoris. This condition generally occurs in fits, which are intermittent and increased by cold, &c. We may perhaps regard as analogous to this the very rare *livor angioneuroticus* ('true cyanosis'), a spotted, dark bluish red hyperæmia, with dull pain, objective cold, and sometimes with fits of hæmaturia, to be referred, probably, to temporary spasm of the little cutaneous veins.

Paralysis of the vasomotor nerves (cutaneous angioparalysis) appears in the form of intermittent ('true blush') or permanent, spotted or diffused, redness and increased temperature of the skin, with accelerated pulsation, paræsthesiæ, and perhaps also with pain in the head, vertigo, swimming of the eyes, loss of sleep, excited heart's action, increased secretion of sweat, &c. In isolated cases this affection has been observed in the hands and feet, coming on with great pain and hyperæsthesia (the erythromelalgia of American authors).

These cutaneous angioneuroses occur chiefly in 'nervous,' hysterical, neurasthenic individuals, and may be excited by all possible injuries (chill, working in water or in caustic fluids, certain poisons, &c.) I need not enter into it more particularly.

What is much more important for us, for the establishment of the special electrotherapeutic indications, is the significance and special pathogenesis of all these vasomotor disturbances. But as this is an impossibility in the present condition of our knowledge, in the uncertainty which still prevails as to the existence and distribution of vasodilators and vasoconstrictors, inhibitory and stimulating vasomotor tracks and centres in the spinal cord, and in the possibility that both of these may be stimulated either directly or indirectly, we shall gain nothing by conjectures; and as you know the position of physiological lore on these matters you may find justification for your proceedings yourselves. Further details would lead me too far in this matter.

The case of Otto, mentioned before (Obs. 138), is an excellent example of vasomotor paralysis, and the following clinical history may serve as one of vasomotor spasm.

139. *Observation by Nothnagel. Vasomotor Neurosis of the Upper Extremities.*—A working woman, aged 49. Six years ago, after a severe chill, creeping feeling in both hands and rending pains up to the upper arm. Improvement after 6 months; occasional improvement only from that time. Severe exacerbation 3 months ago. Condition: Complained of deadness, cribbling feeling and severe pain in both hands and forearms, varying in intensity; improvement with warmth and energetic work, worse with cold and repose; very great pain during the night. Very frequent 'dying' and blanching of the fingers. Sensibility much deadened; all symptoms somewhat stronger on the left side; left hand always somewhat cooler than the right. No tenderness on pressure anywhere. Farado-cutaneous brushing for a long time without any result. Then after a long pause galvanic treatment (A on the plexus, K on the nape, current stabile, for 3 to 5 minutes) three times a week. After three weeks the left extremity quite cured, and the right considerably improved. Gradual cure.

It would be rash to wish to determine the electrical methods of treatment for vasomotor neurosis in the present position of our physiological knowledge. The very highly developed relations with the vasoconstrictors and vasodilators, which not only exist alongside of each other in the peripheral nerves and in the sympathetic, but also occur widely distributed in the central organ, and the impossibility of estimating, even approximately, the share which each of these groups of fibres takes in the vasomotor disturbance which may be present, entirely prevent, for the present, a clear insight into, and therefore a clear method of treatment of, vasomotor neuroses. We are hence compelled to find out empirically, by therapeutical experiment, what is the most useful method in the different cases and forms.

The very vague electrophysiological facts which I collected before (Lect. VII., p. 109) may serve as data. Of these I will only recapitulate the following: that moderate faradic irritation generally contracts the vessels, but that strong faradic irritation, especially faradic brushing, causes a strong secondary dilatation ; that galvanic currents act in the same way, first contracting, then dilating, and that this dilatation comes on more rapidly and strongly the stronger the current is; that, further, KC contracts the vessels, while a continuation of the A dilates them excessively; and that, finally, ascending and descending galvanic currents, stabile, in some nerves, act upon the vessels directly as dilators.

With the help of these rules you will be in a position to construct for yourself a plan of treatment in individual cases, certainly always with the reservation that modifications may perhaps be necessary, and on that only therapeutical experiment can finally decide.

For *vasomotor spasm*, then, the *stabile action of the anode* on the vasomotor nerves and centres (and also on the vessels themselves) is to be recommended; Nothnagel places the anode on the brachial plexus and the kathode on the nape, with a stabile current, from 3 to 5 minutes, with good results. You may also send strong stabile currents in reversed directions through the affected nerves, with a tolerably long duration ; or try to induce dilatation of the vessels by strong faradisation of the nerve trunks, or, finally, by energetic faradic brushing of the skin (directly or reflexly ?). In obstinate cases you may try these various methods in turn.

For *vasomotor paralysis* the opposite course is suitable; you first let the *kathode act stabile*, with a weak current and with repeated interruptions, on the affected nerves and centres ; and some reverses, with not too strong a current, are also desirable, the duration being always short. A slight labile action of the kathode on the nerves and skin may also be tried, but only with a weak current; and also weak faradisation of the nerves and the skin with moist electrodes, or a very short and not very strong action of the faradic brush, from which Seeligmüller saw palliative results, at least, in a case of erythromelalgia. In such cases it is, perhaps, advisable to make use of distant nerve trunks and portions of skin, preferably of symmetrical parts of the body, and not those which are affected by the vasomotor paralysis, for the irritation of the faradic brush; all physiological facts, at least, speak in favour of this; but it is not yet settled what localisation and what strength of stimulation are necessary in order to produce reflex contraction or dilatation in a certain vascular region. Both may possibly be produced. According to the experiments of Rumpf it appears as if weak and medium faradisation were the most suitable to induce contraction on the side not stimulated (after temporary dilatation), while very strong currents cause, after temporary contraction, permanent and pronounced dilatation on the opposite side from the irritation.

But all these methods require to be tested in the cases of disease in which things sometimes present themselves very differently from what was expected from the physiological experiments. And a better judgment with regard to the results of electrotherapeutics in vasomotor neuroses will only be obtained when such therapeutical experiments have been carried out, according to definite methods, in a greater number of cases. For the present we can only say that they are, on the whole, satisfactory, and that they often show themselves rapidly and completely in the slighter cases.

There are many reasons for regarding the rare and peculiar, periodically recurring joint affection, which is described by the name of *Hydrops articulorum intermittens*, as a vasomotor neurosis. This view of the disease involves, necessarily, an experiment with electrical treatment. This was first made by Seeligmüller, without any result, but Pierson reports beneficial results from galvanisation of the nape of the neck in one case. I can only, like Seeligmüller, recommend further experiments. If such a case, then, should come under your treatment I would advise, in the attack itself, the treatment for vasomotor paralysis (see preceding page), applied to the knee, the afferent nerve trunk, and the spinal cord, perhaps also acting reflexly from the other leg, or from the sole of the foot on the same side, chiefly with weak currents. In the intervals, the treatment of the lumbar cord, as well as of the crural and sciatic nerves, with galvanic currents, appears to me to be indicated. The matter is, at all events, worthy of further investigation.

Many skin affections, also, have lately been reckoned among the vasomotoro-trophic neuroses, or at least have been brought into relation with anomalies of the nervous system; of these I would mention the various forms of *erythema*, *urticaria*, and especially *herpes zoster*. These have certainly as yet been of very little interest for electrotherapeutists, but they may furnish a very grateful field of labour for electrotherapeutical investigations. The neurotic nature of the affection is least doubtful in the case of herpes zoster. This occurs sometimes isolated by itself, sometimes combined with neuralgia in analogous situations, and, according to all we know, it appears to be regularly connected with inflammatory processes (neuritis) either in the peripheral nerves or, more frequently, in the spinal or Gasserian ganglia. The galvanic treatment of neuritis would be indicated from this in suitable cases (vide Lect. XXI.) It will as a rule be superfluous, at all events for zoster, as it generally heals of its own accord in a few days. But the presence of herpes zoster is a sign that any neuralgia which may be present depends upon neuritis, and that the treatment must be directed especially to the region of the spinal ganglia or of the Gasserian ganglia. Also it shows that you need not refrain from the galvanic treatment of a neuralgia on account of the presence of herpes zoster.

The circumscribed cutaneous anæsthesias which sometimes remain after herpes zoster are to be treated exactly like other anæsthesias.

Moncorvo and Silva Araujo report brilliant results following the faradic and galvanic treatment of elephantiasis Arabum, with the addition of electrolysis. F. A. Hoffmann has treated chilblains with the faradic current, and has found that they have disappeared, with all their disagreeable sensations, in a marvellous manner, after from 2 to 5 sittings.

Anomalies of the sudorific secretion were formerly included among the vasomotor neuroses. They sometimes attain a certain individuality, present wonderful forms and localisations, and are, indeed, often associated with vasomotor neuroses. But nowadays we know that special nerves and cerebro-spinal centres preside over the sudorific secretion, and therefore that neuroses of the sweat secretion may have a character of their own and may have their special pathogenesis and localisation. Certainly, if we find regularly an increased secretion of sweat in certain vasomotor neuroses (as in angioparalysis), it may be explained by the increased blood supply and the rise of temperature, acting as an incentive to the secretion, but probably not by paralysis of the inhibitory nerves of the secretion. And these sweat neuroses may be quite independent of the vasomotor neuroses.

They appear in the form of *hyperhydrosis* (increased secretion) and *anhydrosis* (diminished secretion), more or less extensive or limited to the local part, very frequently localised in one half of the face, with or without vasomotor disturbances or symptoms of sympathetic affection. The sweat anomalies occur especially in certain conditions of the body—over-heating, movement, taking of nourishment, action of acids on the tongue, &c.

Not much is known about their *electrical treatment.* If the anomalies of the sweat secretion are only a consequence of vasomotor or sympathetic neurosis and the altered circulation caused by them, these disturbances must be treated in a suitable manner. If, on the other hand, they are idiopathic, they must be treated according to the analogy of the vasomotor neuroses—a stimulating procedure in anhydrosis and the reverse in hyperhydrosis. You will, however, easily get into a dilemma with the antagonistic vasomotor effects.

I will mention here another disease, which has, perhaps, of all others the best founded claim to the designation of a tropho-neurosis—*hemiatrophia facialis progressiva.*

The chronic diminution of one half of the face, extending to soft parts, skin and bone, and leading finally to an extreme deformity of the face, may obviously be of neurotic origin, even if nothing certain is yet established as to its more exact nature and the true localisation of the process.

I incline to the view that the disease belongs to the region of the trigeminus nerve; the idea that it lies in the cervical sympathetic, or is occasioned by means of it, seems to me much less probable. It is still entirely uncertain whether it has to do with a lesion of the Gasserian ganglion or with an affection of more central tracks, or perhaps of a trophic centre that is in connection with the origin of the trigeminus.

But experience teaches that this affection, if once it is distinctly developed, is incurable. If, therefore, you accomplish anything by your treatment it will be in the preliminary stages, at the very beginning of the affection. The electrotherapeutic experiments which have hitherto been made have been attended with very little result; but still one would always have recourse at first to the electric current as a cure for this disfiguring affection.

I would recommend the following as the most suitable methods of treatment: galvanisation of the trigeminus, especially of the region of the Gasserian ganglion (transversely through the middle temporal region); then galvanisation of the medulla (transversely through the mastoid processes) and of the cervical cord, in order to influence the nucleus of the trigeminus; further, also, galvanisation of the cervical sympathetic, in order to stimulate the trophic processes by an increased blood supply; and, finally, direct treatment of the face with the stabile and labile action of the kathode, in order to attain the same effect. The treatment must be begun early, and continued for a very long time.

Finally, you must allow me to say a word about the so called *scleroderma*, a very peculiar affection of the skin and the subjacent soft parts, for which also the view of a trophoneurotic and vasomotor origin is more and more gaining ground, and which has, therefore, already become more frequently the object of electrotherapeutical investigations. The vasomotor disturbances which often accompany the affection—the processes which progress under the guise of atrophic inflammation of the skin, atrophy, tension, glistening condition of the skin (reminding one of the 'glossy fingers' of severe traumatic nerve lesions), the shrinking of the subcutaneous tissue, the atrophy of the muscles, the abnormal pigmentation, the anomalies of growth in the hair and nails, the symmetrical occurrence and the progressive character of the disease—all these speak in favour of its being of nervous origin and of its being a trophoneurosis; but still that appears to me to be by no means certainly proved. We must think, then, principally of localisation of the disturbance in the spinal cord and its trophic centres, perhaps also in the sympathetic and its ganglia; it is not possible to say anything more exact about it.

Numerous experiments with electric treatment have been made in the disease; I have myself treated a great number of cases with great perseverance and little result. I have recently treated galvanically a very far advanced case in a young lady, which had existed for 6 or 7 years, and achieved an undoubted improvement with it (combined certainly with arsenic and the inunction of fat). Still more recently I have treated another case.

The method adopted was galvanisation of the cervical and lumbar enlargements of the cord with stabile currents and reversals; then galvanisation of the cervical sympathetic in the usual way; and, finally, peripheral labile (kathode) galvanisation of the skin on all the parts affected (face, neck, chest, upper extremities, especially the hands) so long and with such strong currents that redness of the skin was caused. The result was not merely subjective, but also very plainly objective, although there was, of course, no sign of cure. But this experience has encouraged me to make the affection the subject of electrotherapeutic experiments on further occasions.

Fieber treated a case, limited to the left upper extremity, in the same way with good results, and Schwimmer reports a case *cured* by galvanisation of the sympathetic and of the back. The observation of Armaingaud, who also used the kathode labile (the anode being on the spine), does not refer to a true scleroderma, but rather to a case of myxœdema.

IX. GENERAL NEUROSES. CENTRAL AND OTHER FUNCTIONAL NEUROSES.

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LECTURE XXXI.

Conception of Functional Neuroses—Electrotherapeutical Problems—Removal of the Local Nutritive Disturbance—Influencing of the whole Nervous System and of the Entire Organism—Removal of Definite Causes of Disease—Attacking of Individual Symptoms.

1, Neurasthenia—Various Forms—Nature of the Disease—Methods of Treatment—Results—2, Hypochondria—3, Hysteria—Its Nature—Aim and Methods of Electrical Treatment—4, Epilepsy—5, Neuroses of Co-ordinated Movements—Writer's Cramp—Various Forms—Methods of Treatment—6, Chorea Magna.

Of the diseases of the nervous system in the strictest sense there remains still, for electrotherapeutical consideration, a large group of frequently recurring, serious, and important diseases. These are forms very diverse in kind, but all having this in common, that they may be regarded—at least in the present condition of our knowledge—as so called 'functional neuroses,' i.e. as diseases in which a grosser anatomical lesion cannot be made out with our present means of investigation, and for which the expression 'disturbances of circulation,' so often and so superfluously dragged in, cannot possibly give sufficient explanation. They are diseases, further, whose exact localisation in the nervous system (whether in the peripheral nerves, the spinal cord, the brain, or the sympathetic) is not even always known to us, or for which several of these localisations may be assumed at once ; indeed, for certain forms of these neuroses we assume a general, diffused implication of the whole nervous system, and call them, therefore, 'general neuroses.'

The idea of 'functional neuroses' is at once inviting for the electrical treatment of this form of disease, for you cannot avoid feeling that purely functional, molecular and finer nutritive disturbances may be removed more easily than grosser anatomical changes by a remedy that has such a decided influence on the function of the nerves and on their molecular mechanism. Nevertheless the electrotherapeutics of these functional neuroses is by no means very extensive, and is really only in the preliminary stages of its development. In several of these neuroses electrotherapy has been hardly, if at all, ventured upon; in others it has as yet gone no further than timid experiments, and only a few have been subjected regularly, with corresponding results, to the electrical treatment.

The reasons for this difference are to be found in various considerations—for one thing in the want of knowledge as to the position and nature of the affection, which always has a paralysing effect on therapeutical experiments; then in the fear of evil effects on the forms of disease which are already in themselves very dangerous and progress with marked symptoms of irritation, and in which we dread the presence of a new irritation; further, in the great susceptibility of the patients themselves to all therapeutical influences, and therefore also to the electric current, which induces bad results and an increase in the symptoms; and, finally, in the many bad results of electric treatment in these neuroses, which occur as unexpectedly as undoubtedly, and which, although they may be partly explained by unsuitably chosen or unsuitably localised methods of application, have still acted as a deterrent on further investigation.

Nevertheless it appears to me to be our urgent duty not to give up these trials entirely yet, but to renew them again and again, modified and improved by the daily advances in our knowledge of these vague and remarkable forms of disease; and therefore I shall proceed to describe the latter, although the practical significance of their electrical treatment is not yet very great.

A few sentences will suffice to indicate the problems of electrotherapy in these ailments in general, and then I shall turn to a short description of the special forms, which present so many differences individually that a simultaneous discussion of all is not practicable.

As a first duty—especially in those functional neuroses which may to some extent be accurately localised—*the removal of local nutritive* (*functional*) *disturbances* presents itself; for these the katalytic and alterative actions of electric currents are to be preferred, and they may be carried out by various methods (stabile galvanisation or faradisation, central galvanisation, the employment of weak continuous currents). This aim may also be attained in an indirect manner by influencing the circulation of the diseased part and by direct katalysis (galvanisation of the sympathetic and of the cervical cord, reflex action from the skin, &c.) These procedures may of course be much modified in individual cases.

In the second place you may employ a stimulating, modifying, alterative *influencing of the entire nervous system*, or even of the *whole organism*, as a cure, the former in the so called general neuroses, which affect the greater part of the nervous system at once, the latter partly for the same reason, and partly in order to produce a beneficial reaction on the nervous system by raising the general nutrition and stimulating the entire organism. For these purposes the methods of general faradisation, of general and central galvanisation, and the electric bath are to be preferred.

You may, further, require to *remove special causes of disease*, in so far as they are accessible to the electric current at all, and in so far as they keep up the disease itself or excite the several attacks of it. To this belong, for example, the removal of peripheral neuralgias which may have an influence on the occurrence of epilepsy, chorea, tetanus, &c., the checking of an aura which regularly ushers in an epileptic fit, the cure of ovarian tenderness in severe forms of hysteria, the cure of spermatorrhœa, &c., as causes of spinal neurasthenia, the treatment of tender points in writer's cramp, chorea, hysteria, &c., all of which are to be carried out according to the rules and methods already known to you.

Finally, a very wide field of action still remains in the *combating of individual predominating symptoms* of functional neuroses. Here there are spasms, there paralyses to cure, neuralgias, hyperæsthesias, anæsthesias, and migraines to drive away, vasomotor and trophic disturbances to proceed against, impotence and spermatorrhœa, asthenopia and photophobia, anxiety and sleeplessness to combat, and more work of the same kind, which I shall specially mention further on. This must all be carried out according to well-known methods, suitable for the individual cases. This indication may come so much into the foreground in many cases which present only one or a few symptoms, and whose pathogenesis and localisation are perhaps also vague—e.g. in tremor—that it may form the chief part of the treatment. But in almost all such cases a special regard for methods of central treatment seems to be very desirable.

This is what *may* be done, and what may, of course, be done in the most manifold combinations and modifications. Let us see what it may effect in the various forms of functional neuroses, which often give the electrician very difficult problems to solve. Here, of course, we have to do *only* with their electric treatment. I am very far, be it understood, from placing this in the foreground in all functional neuroses, and I must, therefore, refer you to the handbooks of nervous pathology for the other methods of treatment and the proper choice of them, as well as for the indications for electrical treatment. I will only cite here what you may occasionally attain with the electric current, and tell you how you must proceed with it.

I shall begin with the most frequent, and perhaps the most important, of these neuroses, which is

1. *Neurasthenia* (*Nervous Weakness*).—It is the fashionable neurosis of our time, the 'nervous disease' *par excellence*, and it appears in a thousand wonderful forms. It may be best defined as a high degree of irritable weakness of the nervous system, which progresses with the most varied disturbances of function in every possible region, without our being justified in assuming an anatomical ground for them.

This is not the place to enter in any way upon the symptomatology of this protean and often very obstinate affection; but in your diagnosis you must always remember that the most careful investigation, in spite of the innumerable and lively complaints of the patients, will always give an absolutely negative result (with the exception, at most, of some spinal tenderness on pressure, a slight increase of the reflexes, and coldness of the hands and feet) if you assume that it is a neurasthenia. Every *objective* change, however slight, in the sensibility, motility, reflexes, pupils, and the like, must awake in your minds a doubt of the correctness of this diagnosis. Electrical examination does not generally contribute anything to clearing it up; for it shows, as a rule, absolutely normal relations.

It is advisable, also, with a view to treatment, to distinguish various forms of the disease. There is one in which the cerebral functions are principally affected (*neurasthenia cerebralis*), and which is characterised specially by weight in the head, inability to work, sleeplessness, physical depression, pathological anxiety (fear of places; dread of lightning, of shooting, of human beings, of diseases, &c.), palpitation of the heart, &c. Another principally, although not entirely, affects the spinal functions (*neurasthenia spinalis* and *spinal irritation*), in which weakness and exhaustion, trembling, paræsthesiæ and pains in the extremities, pain in the back, sexual disorders, vasomotor anomalies, &c., are most prominent. Finally, there is a not infrequent combination of both, in which the disturbances extend more or less over the whole cerebro-spinal system (*neurasthenia universalis*) and in which they may occur in the most varied combinations.

All considerations as to the *nature* of this extensive neurosis must exclude the frequently blamed circulatory disturbances (hyperæmia or anæmia), as well as grosser anatomical changes, from the causation. The circulatory disturbances are, at all events in the greater number of cases, not the cause but only the consequence of the affection, and are nothing but the expression of the neurasthenic disease of the vasomotor apparatus itself. Sometimes, however, this may itself be primary (neurasthenia vasomotoria), and may then cause further disturbance by abnormal distribution of blood in the central nervous system. But for the greater number of cases we must fall back upon a *finer nutritive disturbance of the affected nerve apparatus*, whose essential nature, however, is still entirely unknown to us, and for whose functional expression the name of 'irritative weakness' is still the most appropriate.

In the *treatment* of this neurosis, electricity, along with other remedies, is often of very good effect. What has to be done is to remove the doubtful, finer nutritive disturbances in the nervous system, to raise and strengthen the whole organism, and to fight against individual and particularly troublesome symptoms. You may employ either the galvanic or the faradic current. With the galvanic current you must first galvanise the head, the sympathetic, and the cervical cord, in the manner I described fully to you in the electrotherapeutics of the brain, when you have to do with the cerebral form; while in spinal neurasthenia you must galvanise specially the spinal column and the sympathetic, subsequently also the legs, in the way mentioned before. For this application I prefer the ascending direction of the current, following an opinion expressed by Ranke, that the normal ascending current of the animal body may act as a strengthener to the function of the spinal cord, and, especially, as a restraint to the reflex processes in it. If you have to do with universal neurasthenia, both applications must be made, or central galvanisation, which Beard praises so highly.

With the faradic current you may try the same manner of application, as Löwenfeld has recently suggested; but I would specially recommend general faradisation to you as a very valuable method in such cases, the beneficial results of which have been lauded by Beard and confirmed by other observers and by myself. Electric baths, especially the monopolar and dipolar faradic bath, have lately attracted special attention (from Stein, Eulenburg, Lehr, &c.), both because of their convenient employment and because of their undoubted utility. They deserve to be more largely employed in these diseases, especially in 'sexual neurasthenia.' If you find very marked vasomotor disturbances, symptoms of congestion of the brain and spinal cord, you had better not leave untried the treatment with the faradic brush, recommended by Rumpf (the brushing of large cutaneous surfaces on the back and on the extremities).

But a number of *symptomatic problems* may also have to be solved. You will treat headache, migraine, and pains in the back according to the instructions given in the description of neuralgia (Lectures XXVI. and XXVII.); for the feelings of anxiety, with palpitation of the heart, &c., galvanisation or faradisation from the nape to the epigastrium and the cardiac region, and galvanisation of the sympathetic and the vagus, are often useful; for sleeplessness you may try the methods given before (Lecture XVII.), and for prominent vasomotor disturbances what I recommended to you in Lecture XXX. Weakness and pain in the legs may often be helped by direct faradic or galvanic treatment of them; sexual weakness, premature ejaculation, impotence, &c., may often be beneficially influenced by the means which will be communicated to you later (Lecture XXXVII.), while faradisation of the intestine (vide Lecture XXXVI.) often proves useful in constipation.

You see, gentlemen, what a number of indications there are which will test your acuteness and your electrotherapeutic skill to the utmost. In such cases do not forget the cautions which have already been given to you. You will have to do with extremely irritable and sensitive individuals, and you must therefore begin always with very weak currents, and cautious, short applications, testing each individual patient at the commencement of the treatment with regard to his 'electrical sensibility.' You will find great differences between them, which you must, of course, consider well in your therapeutical applications. Regular and systematic procedure is specially necessary in these very tedious and obstinate forms of disease.

The *results* of electrical treatment are by no means always prompt and brilliant, as you may, indeed, imagine for yourselves if you consider that the affection depends to so great an extent on congenital neuropathic diathesis, injuries which have existed for years, &c. You will often get very satisfactory and rapid results, especially in the slighter forms, with little neuropathic disturbance; but frequently a gradual advance towards improvement will only be made by long subsequent treatment, and you will often expend time and trouble entirely in vain in the case of patients whose affection resists even the most circumspect and varied treatment. We are not yet in a position to designate more particularly the cases which are or are not specially suited for electrical treatment; we must first have much more critical experience.

2. *Hypochondria* stands in the closest relationship to neurasthenia, and passes, on the other hand, imperceptibly over into the region of the psychoses. We may define it as a form of melancholy depression, in which the attention of the patient is directed chiefly to diseased conditions of his own body and their possible evil consequences (pathophobia). It is generally developed on the foundations of a neuropathic anomaly of constitution; it comes on very frequently with disturbances of the digestive organs and the genitary apparatus, and gives rise besides to numerous nervous disturbances—abnormal sensations,

sleeplessness, feelings of anxiety, loss of energy, constipation, &c.—and the objective conditions correspond pretty closely with the amount and intensity of the subjective complaints.

Electricity has been used comparatively seldom in this neurosis, and perhaps more seldom than it deserves. You may generally employ the same methods of procedure as in neurasthenia, general faradisation being specially to be recommended. You will often also see very good results from the symptomatic treatment of prominent symptoms—the treatment of constipation by faradisation of the intestine; of impotence by suitable galvanic treatment; of sleeplessness, anxiety, and weight in the head by the different procedures which you already know.

At the same time you must attend to the advice to treat the patients psychically as well, and to employ all your electrotherapeutical procedures from this standpoint and to this end; it is only in this way that you will get good results in these severe forms of disease. I would also remind you to be cautious with the choice of the strength of the current, as many of those patients are very sensitive, and may be made worse, or at least may be easily frightened away, by a too sudden proceeding.

3. *Hysteria.*—This remarkable functional neurosis, with its innumerable symptoms, its changeful course, and its manifold forms, which, however, according to more recent investigations, shows a certain law with all its apparent absence of rule, is a very frequent subject of electrotherapeutics, in spite of numerous and frequently surprising failures, against which many striking successes may be set. On the whole, hysteria is as obstinate against electrical treatment as against all other remedies. This is partly to be ascribed to psychical causes, partly also to the very great irritability of hysterical patients, which is not always sufficiently considered in the application and calculations of the electric current.

The *nature* of hysteria is still entirely obscure, and we are driven back upon the hypothesis of finer, remarkably changeable, nutritive disturbances, which cannot yet be accurately defined. We are even, in many respects, doubtful about the localisation of these finer disturbances, although it is becoming more and more probable that they occur chiefly in the central nervous system; but still a peripheral localisation is by no means to be excluded for a number of symptoms (neuralgia, hyperæsthesia, paralysis, &c.)

Hysteria, also, is an affection which it is extremely difficult to cure, and this may be occasioned, as in neurasthenia (with which hysteria possesses a certain relationship, without being identical with it), partly by the congenital neuropathic affection which plays so great a part in its origination, partly also by the presence of progressive causal injuries, whose removal is not possible. At all events you must guard against too great and certain hopes from the electric current in the treatment of hysteria.

The aim of this treatment is, in the first place, the removal of the disease itself, of the morbid nutritive disturbance of the nervous system—in others words, the bracing and strengthening of the nervous system as well as of the entire organism generally—an aim which is also striven after by nearly all the other remedies for hysteria. *General faradisation* and *electric baths* are serviceable here in the first place, subsequently *central galvanisation* to its full extent, and also, later on, *galvanisation of the spine* with ascending stabile currents, with special reference to the cervical cord, and including the sympathetic in the neck. Considering the excessive irritability of hysterical patients, it is very advisable to try the employment of weak, continuous currents along the spine (with a couple of galvanic disks). The treatment of tender spots on the spine or on other parts of the body often acts favourably on the general affection, and also, finally, the treatment of ovarian tenderness (which may be considered a parallel) as it is practised by Holst—A on the spine, K on the painful ovary, with a stabile current—or according to the method recommended by Neftel in visceral neuralgias (vide p. 543).

In the treatment of hysteria you must pay very special attention to causes. There is hardly any neurosis in which psychical causes play so great a part as in this, and confidence in the physician and in his remedies is the best guarantee for the result, while mistrust will interfere with every remedy.

Strive, therefore, before all things to win the confidence of hysterical patients for yourself and for your remedies, and do not lose it by an unskilful, too strong, or incautious application of the current. Always begin with an extremely weak current and with slight and short applications. I have often considered it desirable to test the influence of the psychical impression upon such patients and their complaints, and I have, therefore, with many of them, begun the treatment by placing the electrodes according to the usual plan, but without closing the current, and have then completed the sitting with the gravest face in the world. It is wonderful how much we may hear of the results of such a sitting, both in good and in bad consequences, but it certainly gives a clear impression how much is to be ascribed to imagination and psychical excitement, and how much really to the action of the current, in such patients; and our therapeutical judgment will be considerably strengthened by it. In comparatively reasonable patients we may produce a considerable psychical impression by the communication of this little deception, and thereby assist the cure; but in others such candour would have exactly the opposite effect, for the hurt vanity of some hysterical patients would not permit them to pardon the physician. It is better in such cases to keep the secret to ourselves and not to let ourselves be further deluded by the many objections of the patients.

Also you must not seek to hurry anything in hysterical patients, but must proceed slowly, step by step, often omitting the treatment, so as not to over-stimulate, and only pressing forward energetically in the case of individual symptoms.

This symptomatic treatment has a very extensive field in hysteria. It does not present anything specific, but is carried out entirely in accordance with the methods given you before, which may, indeed, undergo certain modifications with regard to the general condition of the patients and the hysterical nature of the fundamental affection, but which are not to be much changed in themselves.

For neuralgia and hyperæsthesia you will employ the usual methods, with the cautions which have just been given; and ovarian tenderness requires special consideration in severe cases.

For hysterical paralysis, in the same way, the usual procedure for paralysis in general must be employed in its various modifications. With reference to its diagnosis, I will only remark that the electrical irritability of the motor nerves and muscles is not generally altered in any way, and that the statement of Duchenne, that the electromuscular sensibility is extinguished, as a rule, by no means applies to all cases of hysterical paralysis, so that the circumstance cannot be regarded as a diagnostic or even as a pathognostic token. It occasionally occurs in paralysis of other origin. The therapeutical results in hysterical paralysis are sometimes remarkably prompt (e.g. in hysterical paralysis of the vocal cords[1]), but at other times exactly the reverse, slow and uncertain, so that very long-continued treatment is necessary for cure. This is especially the case in the paralyses which occur in the form of paraplegia.

For anæsthesia you will employ the methods of treatment given in Lecture XXIX., while for the hemianæsthesia of hysterical patients, which is not rare in severe cases, the treatment recommended by Vulpian—local faradic brushing of a circumscribed cutaneous patch of the forearm—sometimes appears to be of brilliant effect.

In these hysterical hemianæsthesias it has been found (Rom. Vigouroux, Estorc) that the tissue resistance of the anæsthetic side is somewhat greater than that of the healthy side, but this difference generally disappears rapidly during the passage of the current.

For hysterical spasm electrical treatment is very often useless, in spite of all possible methods. For contraction the galvanic (stabile descending) current sometimes proves itself useful, sometimes the faradic; and sometimes also the continuous use of a weak galvanic current (Leloir). Severe hystero-epileptic attacks are said to have been sometimes cut short and modified by means of a stabile galvanic current from the forehead to any other part of the body, no matter in which direction, with 10 or 15 cells (Richet, Roux). The sudden reversal of a very strong galvanic current (40 to 50 cells, Trouvé) applied in this way will terminate such an attack immediately, but will not guard against its return.[2]

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[1] Emminghaus has found galvanisation transversely through the mastoid processes useful in hysterical aphonia, but he cannot decide whether the influence is physical or psychical.

[2] Static electricity has recently been employed in Paris, not without effect

For the globus hystericus you may try galvanisation or faradisation of the neck and pharynx, and also the passage of the current from the nape to the epigastrium. This is also good for nervous vomiting, and so is vigorous faradic brushing in the epigastric fossa, while constipation and hysterical tympanitis may be treated by faradisation of the intestine. For vasomotor disturbances, sleeplessness, anxiety, and the like you may also try electricity according to the well-known methods.

As I said at first, the results of electrotherapeutics in hysteria are not brilliant, or at all events they are not to be counted upon, and they are very changeable. It is just in hysteria that the wonder cures occur, especially the magically rapid cures of apparently severe affections, paralysis, &c.; but it is just here also that you will come upon quite unexpected failures, and you must always guard yourselves against ascribing all that you attain to the remedy you employ. In many cases the treatment must be conducted with great patience and caution, if anything useful is to be gained by it. There are no more special indications to be laid down here.

4. *Epilepsy.*—This severe and mysterious neurosis has until now been comparatively rarely made the subject of electrical treatment, although a great number of facts and considerations appear to invite the trial, and although systematic experiments could be very easily carried out in the hospitals provided for it. Such experiments in greater proportion are very much to be desired.

The essential nature of epilepsy is very obscure, in spite of all the critical and experimental investigations with regard to it, and in spite of all the more or less ingenious attempts to explain its form and symptoms. Even the localisation of the affection, which we ventured recently to believe, with tolerable certainty, to be in the pons and the medulla, now begins to be doubtful again, and we seem to stand before a revolution of our views in this respect. The more recent discoveries with regard to cortical epilepsy, indeed, are akin to the thought that the

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(Charcot, Vigouroux), for all hysterical symptoms, as well as for the actual disease itself.

seat of origin of epileptic spasms should be placed in the motor section of the cortex of the cerebrum, an idea which has already been repeatedly combated with more or less energy. We are still far from a definite decision upon the point.

So much at least seems certain, that the real seat of epilepsy is to be found in the brain, and that the nature of it consists, first, in a peculiar disturbance within the brain, which makes itself manifest from time to time by a sort of explosive unloading—an epileptic attack. This disturbance, defined as 'epileptic change,' depends, most probably, not on grosser anatomical changes, but only on finer nutritive and molecular processes, of whose essential nature and exact seat we know nothing at all as yet.

Electrotherapeutical experiments on epilepsy have been made by several observers. R. Remak has declared certain forms of epilepsy, which according to his opinion proceed from the cervical part of the spinal cord or from the sympathetic, to be suitable for galvanic treatment. Althaus has more recently published a number of good results, and Benedikt also has pronounced in favour of electric treatment of epilepsy. But it does not appear that they have found many followers.

There is, of course, nothing to be done for the attack itself with the electric current; you must direct your whole energies to removing the epileptic change in the brain. This may be done directly or indirectly, by the removal of the causes or by reflex action.

To influence it directly the katalytic and vasomotor actions of the current are, of course, alone suitable—the direct treatment, therefore, of the head, the cervical sympathetic, and the cervical cord. Althaus recommends galvanisation transversely through the mastoid processes and galvanisation of the sympathetic. I have employed the following method in my more recent experiments, having regard to the possible cortical origin of epilepsy: first, treatment obliquely through the head, from the temporal region and the upper part of the forehead on one side (anode, large head electrode) to the opposite side of the nape (kathode, large electrode), stabile, with a very weak current (5° to 15° N defl., 4 to 6 cells) from $\frac{1}{2}$ to 1 minute on each side; and then longitudinally from the forehead (anode) to the nape, also from $\frac{1}{2}$ to 1 minute. In this way the cerebral hemispheres, the motor regions, and the medulla will be influenced sufficiently. In many cases, especially if vasomotor symptoms are well marked in and between the attacks, I add to this galvanisation of the cervical sympathetic. Very weak currents, careful placing and removing of the electrodes, long-continued and consecutive treatment are unconditionally necessary.

Careful trials with the faradic current though the head appear to me to be also justifiable, in somewhat the same way as in the treatment of migraine.

An attempt may be made to influence the brain indirectly, by means of general faradisation. Althaus recommends very highly the galvanic treatment of that peripheral nerve region which is the seat of the aura. If any tender points or galvanically painful spots can be made out, you may direct the treatment to them, and also if a neuralgia or a peripheral nerve injury, a cicatrix, or the like may be suspected to give rise to the epilepsy, even if it is not the seat of the aura.

The results as yet are but few, but Althaus communicates several very striking ones. I have myself treated individual cases with electricity within the last few years—certainly employing other remedies at the same time—and have received a decidedly favourable impression from it, so that I am much encouraged to further attempts. Two long-standing and severe cases, in particular, were improved, to a surprising degree, by a combination of bromide and electricity, and subsequently cold water and electricity, so that I am inclined to see, in electrical treatment, an excellent assistant, at least, to the sovereign remedy, bromide. It is urgently to be desired that exhaustive experiments should be made in this direction, in which the attention should be fixed first on the galvanisation of the brain, secondly on that of the sympathetic and of the cervical cord, and thirdly on general faradisation. It is only when we have a greater number of individual experiences that we shall be in a position to set up more accurate indications for the selection of cases for electrical treatment, and for the choice of the methods to be employed.

5. Under the name of *neuroses of co-ordinated movements* we include all those neuroses—nearly always purely functional—which have this in common, that in certain complicated and more delicate occupations, and *only* in these, disturbances of movement occur, which embarrass the performance, or even render it quite impossible. The type of this neurosis, and the most frequent form of it, is the so called *writer's cramp*, but analogous disturbances occur also in all occupations—in drawing, sewing, piano and violin playing, milking, telegraphing, cigar-making, &c.

There is no doubt that in these neuroses we have not to do with a single morbid type—a constant form of disturbance—but that they must include various kinds of disease, all of which cause the disturbance of certain functions. It is only in some individual cases that distinctly localised conditions of spasm and paralysis and more accurately recognised peripheral nervous and muscular diseases may be found; and these are the more favourable forms, in which the treatment has certain tangible data on which to be based.

But even in the purely functional, typical forms the affection may manifest itself in a variety of ways—either as a spasm showing itself in a definite manner on writing (spastic form), or a trembling occurring at the same time (tremor-like form), or, finally, as an exhaustion and weakness of the hand and arm, coming on with writing and constantly increasing (paralytic form). But it is characteristic of all these forms, and even necessary for their full comprehension, that examination reveals no other disturbance of motility or sensibility. Electrical testing shows, as a rule, no great changes; I at least have not been able to find any noteworthy qualitative or quantitative disturbances of the faradic or galvanic irritability in a number of carefully investigated cases, and certainly the changes which have now and then been made out by other observers have contributed nothing to the clearing up of the diagnosis.

We are, therefore, still pretty much in the dark with regard to the essential nature of this form of disease, although we know that it has close relations with neurasthenia, and that we have to do certainly with irritable weakness localised in definite parts of the nervous system, the result of over-exertion. It is probably to be located chiefly in the central nervous system, but we do not know whether in the spinal cord, the crura, or the cortex of the cerebrum, and an implication of the peripheral apparatus, the nerves and muscles, is by no means to be excluded. It is most likely that we have to do with various localisations and various lesions in the individual cases.

This uncertainty naturally reacts on the electrotherapeutic methods; but we may certainly assume that various applications will be efficacious, and we have only to find the proper one in the individual case. If any peripheral disturbances are present (paresis, atrophy of individual muscles, neuritis, anæsthesia, &c.) they must first be treated; if well-marked neurasthenia, you must devote yourself first to its cure.

For the rest, you must limit yourself to the direct treatment, and for that purpose endeavour to influence the whole motor apparatus, from the cerebral cortex down to the muscles, if not all at once, at least successively and methodically. In the first place, you must undertake the galvanic treatment of the head, transversely, longitudinally, and obliquely, with the methods and the strength of current which you know; then the treatment of the cervical sympathetic and especially of the cervical cord, after different methods, according to the nature of the case (either ascending stabile, K acting principally on the cervical cord, or stabile anodic treatment, as has been recommended for other forms of spasm; vide p. 558). To this may, finally, be added peripheral galvanisation of the nerves and muscles, either labile, in the tremor-like and paralytic forms, or principally with stabile currents, in the spastic form. Comparatively weak currents are always to be chosen, and all overstimulation of the motor apparatus is to be avoided.

Moritz Meyer has got very good results by treating tender spots on the spinal cord, the brachial plexus, &c. It is only to be regretted that such tender spots occur so rarely, but you must seek diligently for them in any case, so as not to miss this chance of successful treatment. The wearing of simple galvanic elements on the arm and neck in various positions has also proved itself, in my experience, of at least palliative utility in certain cases.

A number of cases may show themselves amenable to faradic treatment, especially where there is peripheral disease of the nerves and muscles. Localised faradisation may generally be carried out with moderately strong currents, and in special cases combined with farado-cutaneous brushing. Neftel has obtained good results in some cases by means of energetic and prolonged electrical gymnastics of the muscles of the forearm with 'swelling' faradic currents of great intensity.

For the various forms of these professional neuroses (writer's, sewer's, piano or violin player's palsy, &c.) the applications must, of course, be modified in a suitable manner.

The *results* are generally scanty. Improvement in the writing, &c., may certainly appear for a varying length of time during and after the galvanisation, but it does not continue, and progressive improvement and final cure occur only in the smallest number of cases; and even in these, very long-continued and consecutive treatment is always necessary; and this must be supported by the patient's strict adherence to other measures of treatment, and especially by absolute abstinence from the hurtful employment.

6. *Chorea Magna* is a very peculiar neurosis, which shows a certain relationship to hysteria and the psychoses, but which can still undoubtedly claim its own individuality, and which presents a very characteristic picture of disease. It is, on the whole, a very rare affection, and it becomes more rarely still the object of electrical treatment. It consists in attacks of disturbed consciousness combined with ecstasy and with powerful co-ordinated movements and spasms (crying, dancing, singing, jumping, rolling, &c.), which may exhibit very eccentric forms and an astonishing duration and obstinacy.

The *nature* of this neurosis, which occurs principally at the period of puberty and under the influence of neuropathic disturbances, is still completely obscure, but it must be dependent on a functional disturbance of the brain.

The only part which can fall to electrotherapeutics here is to act as a tonic on the nervous system, by means of general faradisation or galvanisation, electric baths, and other similar forms of application, and so to prevent a return of the attacks. The experiment might be made also to act in a soothing manner on the excitable nervous system by cautious galvanic treatment of the head, or by central galvanisation, and so to heal the disease by direct influence in specially obstinate and chronic cases.

I do not know whether the attack itself could be cut short by suitable methods of galvanisation, as it can in the severe hysteroepileptic attacks; this point has not yet been investigated.

LECTURE XXXII.

7, Chorea Minor—Its Seat and Nature—Electrical Treatment—8, Tetanus—Experiences—Methods of Treatment—9, Tetany—Its Characteristics—Electrical Excitability—Nature and Seat of the Disease—Electrical Treatment—10, Catalepsy—11, Tremor—12, Paralysis Agitans—13, Athetosis—14, Morbus Basedowii—Characteristics and Seat of the Disease—Methods of Electrical Treatment—15, Vertigo—16, Diabetes Mellitus and Insipidus.

7. *Chorea Minor.*—This extremely frequent neurosis has often been the subject of electrotherapeutical experiments, and occasionally with unquestionable advantage.

Chorea minor also is in many respects a vague and uncertain disease. Discussions with regard to its seat and its nature are still going on, and the views of investigators show many contradictions. It is probably a neurosis localised in the brain, but that is not yet quite certain, and an implication of the spinal cord cannot be entirely excluded. It is probably in many cases only a functional nutritive disturbance, but now and then grosser anatomical changes are to be found. We do not even know whether a special kind of irritation or a special seat of the irritative lesion is the more important factor in the production of the neurosis and of the several types of the abnormal muscular contractions; but it is probable that a special seat of lesion is the more important. We must consider chiefly the grey substance of the central ganglia and the motor part of the cortex, with reference to this localisation.

The play of symptoms in chorea minor, from its slightest indication in individual muscular twitchings up to the most universal and severe forms of spasm, is so characteristic that it can very seldom be mistaken. Electrical examination gives no satisfactory results. It has repeatedly been said that in chorea an increase of the faradic and galvanic irritability of the motor nerves is present (Benedikt, M. Rosenthal, Gowers), and that this is specially easy to show in recent cases of hemichorea; but I have not been able to persuade myself of this, in spite of very careful examination, so that it cannot be a constant occurrence. The tender spots also which Rosenbach discovered in one case, by means of the galvanic current, along the spinal column and on various peripheral nerves, are to be found only in the rarest cases.

Various methods have been recommended and employed for the electrical treatment of chorea minor. Some galvanise the brain principally, and I also consider this plan to be the most correct in the present state of our knowledge. I let the head be treated in such a way that the above-mentioned motor section of the brain may come to lie directly between the electrodes, i.e. obliquely from the region of the central convolutions (vide fig. 29, anode, large head electrode) to the opposite side of the nape (kathode, large electrode) on both sides for ½ to 1 minute, with a weak current (4 to 8 cells Stöhrer, 10° to 15° N defl., 1 to 4 ma.); or also, as O. Berger recommended, with divided anode on both vertical regions, the kathode being in the hand or on the back, for 5 or 10 minutes. The galvanisation of the sympathetic and of the cervical cord may be carried out as well, in order to act indirectly by the katalytic influence.

Others have recommended principally the treatment of the spinal cord, with weak, ascending currents, which are to be applied to the spine partly stabile, partly labile; and it is specially noted that weak currents and short sittings are to be preferred in such cases. You may occasionally try this plan also. Moritz Meyer, on the other hand, treated his cases with 24 to 30 times repeated closures of a strong current, and Leube has also employed a very strong current with effect.

If tender spots are found, it is generally very useful to treat them in the usual manner, with the anode stabile (Moritz Meyer, Rosenbach).

The faradic current has also been tried a great deal, especially in earlier times, but it has shown no very great results;

I would be most inclined to advise a trial of general faradisation, especially in cases of relapsing chorea in children of a nervous constitution.

The *results* of these methods of treatment are very difficult to estimate in a disease of such diverse intensity and course as chorea minor. It has been very much praised by some authors, and by others it has been recommended. My own experience cannot show very brilliant results. I have failed especially in long-standing cases in adults; but, on the other hand, it appears to me that recent chorea in children may certainly be favourably influenced, and in many cases cut considerably shorter, by electrical treatment. Still I cannot give any definite details on the subject.

8. *Tetanus* has as yet been only seldom made the object of electrical treatment. It seems, indeed, a risk to undertake to proceed against such a frightful spasmodic disease, with such severe symptoms and such a dangerous course, and in which cutaneous irritation is apt to be followed by a fresh outbreak of spasm, by means of electricity, the nerve stimulant *par excellence*. Still we might venture, on the ground of our knowledge of the soothing action of the galvanic current and of its inhibitory reflex effects on the spinal cord (Ranke), to make a trial of its resources even in this serious disease. Some remarkably good results have, indeed, been reported from these trials (Mendel), but in judging of them the greatest caution is necessary, because so many cases of tetanus tend of themselves to a cure.

The seat and nature of tetanus are, in spite of repeated and searching investigations, not yet perfectly clear; and the constantly renewed attempts to refer tetanus back to grosser anatomical inflammatory processes in the spinal cord have not led to generally accepted results.[1] In spite of this, however, a spinal seat for the affection—including, of course, certain parts of the medulla (trismus)—is by far the most likely, although grosser changes cannot be found; and therapeutical attempts are to be directed to these parts in the first place.

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[1] Vide Fr. Schultze, 'Ueber dic anat. Grundlagen des Tetanus,' Mendel's *Neurol. Centralbl.*, 1882, No. 6.

Isolated experiments with electricity have already been made, by Italian authors, in tetanus. They passed galvanic currents from the vertex to the buttocks or to the feet for hours together, and seem to have seen a certain amount of good result from it (as also in hydrophobia). Mendel, however, was the first to treat two undoubted cases of tetanus galvanically in a systematic manner, and to obtain a cure from this treatment. He applied the anode to the muscles or to the skin of the extremities, the kathode being on the spine over the cervical and lumbar swellings (sometimes with a reversal of the current), and employed weak stabile currents for a few minutes, and found that the tetanic rigidity disappeared with tolerable rapidity, the improvement continuing after the sitting and progressing gradually to cure. It cannot be decided how cure took place in these cases, whether by the action of the current on the spinal cord, or on the muscles, or on the peripheral sensory nerves; but it would almost appear as if the last-mentioned factor had a considerable share in the result. In the works of Legros and Onimus there is a very detailed account of a case of tetanus which was treated with very large doses of chloral and at the same time with the galvanic current, and was cured; from which it would appear that the employment of descending, stabile, galvanic currents on the spine is of good influence on the spasm itself, relaxing the muscles and bringing relief to the patients. The sittings lasted for 1 or 2 hours, and were employed from 1 to 3 times a day. The current ought not to be too strong, and the electrodes selected must be large. This observation, however, leaves doubtful the real nature of the curative action.

From these few facts, definite conclusions as to the therapeutic value of electricity in tetanus generally, and as to the methods to be employed in particular, can hardly yet be drawn, and our ignorance of the essential nature of the disease scarcely allows us to try an *a priori* rational method. If a case were to come before me, I should employ, in the first place, a direct action of the galvanic current on the spinal cord, first with the anode, with a weak descending current, stabile, for a long time. Mendel's results, however, indicate a simultaneous action on the peripheral parts, especially on the peripheral sensory and mixed nerve trunks, so that the anode should also be applied to them. At the same time it will be necessary to observe carefully whether the simultaneous application of the kathode on the corresponding section of the spinal cord or on an indifferent spot merits the preference. There is, in any case, ample room for further experiments on this subject.

9. *Tetany.*—A much more successful field for electrotherapeutical activity is furnished by the peculiar and not very rare form of spasm which is called tetany, and which has already been repeatedly mentioned by me, on account of its great electrodiagnostic interest.

By tetany we understand a spasmodic disease, which shows itself in painful tonic spasms of special groups of muscles, occurring in a periodic and paroxysmal manner, affecting principally the upper extremities, more rarely the lower, and sometimes also other muscular regions of the trunk and head.

More accurate observations have proved that in this disease an excessive increase of the irritability of the motor nerve apparatus concerned may be demonstrated in various ways. It betrays itself by the onset of characteristic spasms on the compression of the great nervous or arterial trunks of the extremities (Trousseau's symptom); also by the great increase of the mechanical irritability of the nerves and muscles, first discovered by Chvostek, confirmed by N. Weiss, Fr. Schultze, and others; and, finally, by considerable increase of the electrical irritability of the motor apparatus, first accurately determined by me, and since established as an almost constant phenomenon in tetany by many observers (Chvostek, Fr. Schultze, Eisenlohr, N. Weiss, and others). A careful electrical examination, therefore, is an indispensable aid to a correct diagnosis in this disease.

You will find, as I have already mentioned and illustrated by examples (Lecture IX., p. 163 et seq.), great and simple increase of the electrical irritability in nearly all the nerve regions of the body, most intense in those directly affected with the spasm. In the faradic examination the nerves respond to a remarkably small strength of current. In the galvanic, KCC appears extremely early, as does AOC; KCTe comes on very soon, as well as ACTe; and—what is specially important and characteristic—AOTe is very easily induced. Chvostek has even observed KOTe in two cases. This increase of irritability shows itself first in the nerves of the trunk, but not always markedly in the facial region, although this has been recently observed by Chvostek and N. Weiss; and it occurs not only during the actual disease and during the attacks, but also in the free intervals and even in the longer periods of apparently complete health, so that it may serve, like Trousseau's symptom, to show the affection while it is still 'latent.'

Authorities are not yet agreed as to the *nature* and *seat* of the lesion. Pathological anatomical examination has not yet given indubitable results; but the minute critical investigation of the symptoms makes it probable that we have to do with a condition of enormously increased irritability of a great part of the motor apparatus, depending essentially upon finer nutritive, molecular disturbances, whose special seat and point of origin are most likely in the anterior grey substance of the cord (with or without implication of the grey motor ganglia in the medulla). Everything else, however, as to the finer processes in this increase of irritability, as to the physical cause itself (whether it is of a circulatory, inflammatory, or toxic nature), is nothing but conjecture.

In the meantime we must make the view which has just been mentioned a basis for our methods of treatment, and it is easy to deduce therefrom that for the electric treatment of tetany the galvanic current with its modifying actions is principally to be applied.

The most rational method is the stabile action of the anode with gradual cessation, applied to the parts which are the seat of the disease, more particularly to the cervical cord, the whole spinal cord, and the individual nerve trunks, the kathode being on the sternum. All the parts are to be thus treated in their whole extent, and the peripheral nerves may best be influenced by applying the anode in the neighbourhood of the muscles and drawing it slowly upwards to the plexus.

It must not be forgotten that other applications (K stabile, with rapid KO, &c.) may prove useful, if we desire to attain a katalytic action; you must not, therefore, give up the treatment if the first method fails.

You may further proceed to test the value of the faradic current—faradisation of the spine with large electrodes and medium currents, and also of the nerve trunks. I would not advise stronger faradic excitation or the employment of the faradic brush.

It is self-evident that the anodic treatment may be tried during the attack itself. I believe I have repeatedly seen immediate relief and arrest of the attacks from this remedy, and Eisenlohr also has repeatedly demonstrated a similar effect by the soothing action of the anode. Of course it must also be continued in the intervals, and for some time after the cessation of the attacks—for as long, indeed, as Trousseau's phenomenon or any considerable increase of electrical excitability can be detected.

We have no very extensive experience of the curative *results* of the electrical treatment of tetany. The cases which have been published, however, are almost entirely favourable, those related by Eisenlohr specially brilliant; and my own recent experiences decidedly speak in favour of it.

10. *Catalepsy.*—This very remarkable disease, as to whose nature and origin we are still so much in the dark, gives few indications for the employment of electricity. Owing to the great rarity of the affection, and to the manifold combinations in which it occurs, extensive and careful therapeutical investigation is almost impossible.

Electricity has sometimes been used in catalepsy as an energetic stimulant, with the view of relieving the disease and snatching the patients out of their rigidity and want of consciousness by powerful excitations. This may certainly have some effect, and for this purpose the faradic brush, applied in an efficient manner, is to be recommended. Strong faradisation of the nerve trunks and of the muscles may also be of service.

As a special remedy for catalepsy, electrisation of the nerve centres is to be employed in preference to other measures; and yet I have tried first central galvanisation, according to Beard, then galvanisation of the head and of the cervical sympathetic, as well as strong galvanisation and faradisation of the spine, but generally without marked result. I consider the trial of general methods of application, general faradisation and the electric bath, to be also very advisable. As far as experience goes, however, we must not expect much in this obstinate and severe affection.

The most favourable form, hysterical catalepsy, belongs to the domain of hysteria, and must be treated according to the rules laid down for the latter disease.

11. *Tremor.*—The symptom of trembling may occur under various aspects and from different causes; but here those forms only are meant which occur with a certain individuality—e.g. senile tremor, the various kinds of toxic tremor (from alcohol, mercury, and lead), neurasthenic tremor, occurring so often in nervous individuals, tremor after acute diseases, and idiopathic tremor of isolated extremities, &c.

You will not expect me to detail the special characteristics of these individual forms of tremor, most of which give the impression of irritable weakness, and consist in an insufficient, vacillating performance of individual movements, and not in a true spasm. Electrical examination gives no valuable results in such cases.

There is not much to expect from electrical treatment, as success depends really upon the fundamental affection which causes the symptom. The methods to be preferred are to be selected according to the general symptoms and the causes which can be made out. A moderately stimulating and at the same time tonic and strengthening method of treatment must be chosen.

Where the tremor is more local you must begin with moderate galvanisation or faradisation of the parts concerned and of the section of the central nervous system belonging to them, and repeat it regularly until a cure is effected. As we have generally to do with the upper extremity, the treatment of the cervical cord (if necessary also of the brain) and direct electrisation of the nerve trunks and muscles of the upper extremity, with moderately strong currents, is indicated. Thus we can sometimes obtain very good results (cf. Obs. 125).

If the tremor is more general, on the other hand, especially in the forms which depend upon toxic influences, you must trust more to general methods of treatment, and employ either central galvanisation or general faradisation. The electric bath is very specially lauded by French authors for toxic tremor, especially that of alcohol and mercury. Paul lets such patients have a faradic bath, lasting for half an hour, every other day. During the bath the patients feel decidedly relieved, but after it rather worse, a definite improvement only taking place on the following day. But it must be admitted that the results are often extremely unsatisfactory, and I have treated many cases of tremor after typhus, &c., with all possible remedies in vain. Beneficial results cannot, at all events, be predicted with certainty.

12. *Paralysis Agitans.*—This is, no doubt, the severest and most obstinate form of tremor—trembling paralysis—an entirely independent neurosis with an extremely characteristic, typical symptomatology. It is a disease of advanced life, the seat and real nature of which are still comparatively unknown, although it has recently become more probable that it depends upon an affection of the brain.

I need not enter here upon a detailed description of the very characteristic tremor which generally begins in one upper extremity—in the hand—and then passes over to the lower extremity of the same side, and later to the other side; nor describe the peculiar position of the body and the marked expression on the face of such patients, their disagreeable subjective sensations, their inclination to fall either forwards or backwards, their muscular tension, &c. Electrical examination gives us no assistance, the excitability being generally perfectly normal.

The disease appears to be incurable. The cures which are reported by various authors (R. Remak, R. Reynolds, Mann) have not been proved, and they depend probably upon errors of diagnosis, upon confusing other forms of tremor with paralysis agitans. In recent years, in which the disease has been for the first time exactly defined and made accessible to a precise diagnosis, no case of cure, or even of considerable improvement, has been known, in spite of numerous therapeutical experiments, especially with electricity. Chéron alone gives a remarkably large number of successes (treated transversely through the mastoid processes); but his diagnoses leave room for well-founded doubts, and no subsequent trustworthy observer has seen anything similar.

You will, therefore, hardly expect more than a passing relief, or at the most a temporary standstill of the affection, even though you may, for the sake of their comfort, feel inclined to make the poor patients hope for a little more.

The most successful method of treatment consists in the galvanic applications to the head, obliquely and longitudinally, with large head electrodes, as well as the sympathetic and the cervical cord in the way that I have so often described to you. To this may be added descending stabile and moderate labile currents through the peripheral nerves and the muscles.

The faradic current appears to me of no use. But central galvanisation, or perhaps general faradisation, might perhaps be tried in appropriate cases.

The recent experiments with *electric baths* have, indeed, resulted in undoubtedly beneficial effects, of at least a palliative nature. Among others the unipolar or bipolar faradic and, by Eulenburg, the unipolar K bath has been found of service; and, in consequence, the hitherto unsatisfactory results of electrical treatment may, perhaps, improve gradually. My own attempts with the former methods have never effected more than a certain amount of relief to the patient, with now and then a suspension of the symptom.

13. *Athetosis.*—This spasmodic neurosis, first described by Hammond, sometimes occurs alone and idiopathically, but oftener as a sequela of cerebral hemiplegia (athetosis post-hemiplegica), when it is related to post-hemiplegic chorea and analogous tremors. It consists in peculiar, rolling, twitching movements of the hand and fingers, with a characteristic position of the parts, which do not so much affect the arm, but sometimes extend to the foot and leg.

The seat and nature of this disturbance of movement are not yet known with certainty. It is generally assumed, and probably with justice, that it owes its origin to a disturbance in the brain ; but this does not appear to me so very certain, and post-hemiplegic athetosis (and the hemichorea which is analogous to it) may proceed from the spinal cord, in the same way as the late rigidity of hemiplegic patients is occasioned by a secondary implication of the cord. It is not quite certain, either, whether a particular *seat* or only a particular *kind* of irritation causes this strange anomaly of movement. Electrical examination throws no further light on the subject.

Electrical treatment must address itself, in the post-hemiplegic form, to the fundamental affection, and in the idiopathic form to the central nervous system, to the brain and spinal cord. It must include, therefore, galvanisation of the head, the cervical cord, and the sympathetic, according to the usual methods ; and, in addition, application of the anode on the nape, and the kathode on the principal nerve trunks of the extremities. Gnauck saw very good results (cure) from descending stabile currents to the cervical cord and the muscles ; and E. Remak recommends here also anodic treatment of the nape of the neck. I have myself treated several cases without result, although once, in the case of a girl of 20, with double-sided athetosis, remaining after an inflammation of the brain, I attained, after long-continued regular treatment, decided improvement and greater use of the hands.

14. *Basedow's, or Graves', Disease. Exophthalmic Goître.* —A great deal has been done, argued, and written about this tolerably frequent neurosis, and yet it cannot be said that a very satisfactory definition or explanation of it has been found.

It is characterised in a very striking manner by the well-known triad of symptoms, exophthalmos, pulsating goître, and palpitation of the heart, one or another of which may occasionally be wanting ; and this triad is nearly always combined with numerous other nervous symptoms, with marked nervous weakness, and irritability. All the more recent investigations indicate, with increasing certainty, that the *seat* of the disease is most likely to be found in the upper cervical cord and in the medulla. We do not possess as yet any plausible theory as to the real *nature* of the affection. Probably it is only a functional neurosis, or it may consist of disturbances which generally have a tendency to pass off and to be cured, although they may sometimes leave permanent sequelæ behind them.

Since R. Remak's recommendation and v. Dusch's first attempts to cure Basedow's disease by means of the galvanic current, very many trials have been made in this direction, the most successful of which have been those of Chvostek, who has published several works on the subject.

The method of treatment, according to our present views, must be turned first of all to the cervical cord and the medulla, but the treatment of the sympathetic, and of the vagus in the neck, must also be undertaken to combat the principal symptoms.

The galvanic current must be used almost exclusively. The first thing is the treatment of the cervical cord with ascending stabile and labile currents, the anode being between the shoulder-blades or lower, and the kathode on the nape and along the whole spine. Only very weak currents are to be recommended (6 to 8 cells Stöhrer, 15° to 20°N defl., with 150 GR or 1 to 5 ma.) for from 1 to 2 minutes. I have also frequently passed the current transversely and obliquely through the head at the same time, in order to influence the medulla directly; also with very weak currents and short duration. And, finally, the regular galvanisation of the sympathetic and of the vagus in the neck may be undertaken, in the usual manner, A being on the cervical vertebræ and K on the nerves mentioned, from the lower jaw down to the clavicle. This was almost exclusively practised by some observers when the affection was thought to be principally situated in the sympathetic, and it has frequently given good results (Moritz Meyer). This application is said to be principally efficacious against the violent, tumultuous, and abnormally frequent action of the heart. Future observations will show whether the treatment of the heart itself with strong galvanic currents, suggested by v. Ziemssen, in order to produce a retardation of the heart beats, is practicable, and whether it is advisable in these very irritable and sensitive patients; I would suggest great caution in the trials.

A direct galvanic treatment of the goître has also been tried, in some cases with success; either transverse passage of the current through it, or a short and not too weak action of the kathode, is to be recommended.

For the exophthalmos I have often tried passing a weak galvanic current transversely through the orbits, from one temple to the other, and at the same time longitudinally from the nape to the closed eyelids. I cannot venture to say whether it was of any real use. Others treat it by placing one pole on the superior ganglion and the other on the closed eye.

I employ the usual methods of treatment for the paresis of the ocular muscles which is nearly always present in the more severe cases.

The indubitably close relation of Basedow's disease to neurasthenia, and the customary presence of all kinds of neurasthenic symptoms, point to an application of the methods of treatment employed in neurasthenia; and therefore it does not seem out of place to try general faradisation (Rockwell), and perhaps also electric baths.

It is self-evident that, besides the electrical treatment, various other possible forms of treatment—medicinal, dietetic, and balneological—ought not to be neglected.

The *results* of galvanic treatment in Basedow's disease are, on the whole, satisfactory. There is often an immediate and decided result in the diminution of the frequency of the pulse, or this may come on gradually in the course of the treatment (v. Dusch, pulse fell from 130 to 70 and 64; Chvostek, from 120 to 92, from 132 to 110, from 120 to 80; A. Eulenburg, from 108 and 130 to 84 and 70, &c.) The whole course of the disease is often very quickly modified and relieved, and the subjective troubles—weakness, &c.—of the patient removed. But generally a very long course of treatment—30 to 100 sittings or more—is necessary. The exophthalmos alone often continues for a very long time and defies all treatment; but the thyroid enlargement is more readily reduced.

15. *Vertigo.*—There is not much to say about the electric treatment of vertigo; but the ease with which symptoms of giddiness can be induced by means of the galvanic current seems to invite the trial of this remedy for the same symptom

under pathological conditions. So far as I know, however, this has not been done in an efficient manner.

Giddiness is, in the great majority of cases, only a symptom of various diseases of the central nervous system, as well as of the vasomotor nerves and perhaps also of other organs (reflex vertigo, gastric vertigo, ocular vertigo, vertigo in disease of the labyrinth, in Menière's disease, &c.) In all these cases the treatment of the fundamental disease is of chief importance, and in so far as it requires and admits of the employment of electricity, vertigo may also be cured by similar measures. It is only rarely that vertigo will be treated independently, from a symptomatic standpoint.

Vertigo, however, may occur to a certain extent independently, as the most important and, to the patient, the most prominent symptom. The cases are not rare in practice where complaints are made of giddiness, and yet where we can find nothing special even on the most minute investigation, and where we remain in the dark as to its real cause and pathogenesis. In such a case you may try, among other things, the electrical treatment of vertigo. The obscurity of the pathogenesis makes an accurate definition of the methods difficult; but, as the intracranial organs are doubtless the primary source of the vertigo, the galvanic and faradic treatment of the brain is to be tried first, with galvanisation of the sympathetic; and if signs of circulatory disturbances in the cranium are present, reflex action upon the cerebral circulation (after Rumpf), by means of farado-cutaneous brushing, may be useful. If vertigo exists along with a decided tendency to fall towards one side, which is not often the case, the physiological results of the production of vertigo may be tried (vide Lecture VII., p. 117)—i.e. the application of K on the side towards which the patient tends to fall, A being on the other side of the head or on an indifferent spot on the trunk.

But our therapeutical investigations must be multiplied before we can say anything positive on this point.

16. *Diabetes Mellitus and Insipidus.*—The view which is constantly gaining ground more and more, that disturbances of the nervous system are the essential and ultimate cause of at least

a part of the cases of diabetes, has, of course, given rise now and then to electrotherapeutic experiments in these diseases.

With regard to *diabetes mellitus*, this has only been done to a limited extent as yet, and, as it appears, with little result. All the experience that I have is as good as negative. Neftel, on the other hand, reports a very favourable result in the case of a woman who suffered from advanced diabetes mellitus for several years (9% of sugar with a mixed diet), and in whom an extraordinary improvement resulted from galvanisation of the brain, according to Neftel's method (p. 339), all subjective symptoms disappearing and the sugar falling to 1%. Galvanisation of the sympathetic was afterwards added. Beard has attained improvement in two cases from 'central galvanisation,' and Le Fort[1] great improvement from the permanent application of a weak current of two cells, from the nape of the neck to the region of the liver.

The *methods* of electrical treatment may be inferred from the universal theoretical views as to the origin of neurogenic diabetes mellitus—treatment of the cervical cord and the medulla, in the usual way, and simultaneous treatment of the sympathetic, with weak currents, for a few minutes daily. Suitable electrical treatment of the solar plexus, of the dorsal cord, and, perhaps, also of the liver might be thought of. Systematic and rational experimentation on this subject is very much to be desired.

Electricity has been much more frequently employed for *diabetes insipidus*, the neurotic origin of which is much less doubtful from the outset, although there is still great uncertainty as to the exact 'how' and the 'where' of the primary lesion. Some fortunate results also encourage us to further researches. Seidel reports great success in a case which had lasted for more than a year, and had become almost stationary, with small variations in the daily amount of urine. Energetic galvanisation of the region of the kidneys caused rapid improvement, and in the course of a few weeks cure, with increase of weight. Clubbe cured an obstinate case by means of faradisation of the renal region, and Althaus even claims to have cured a long-standing case by a single application to the medulla.

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[1] Le Fort, *Gaz. des Hôp.*, 1872, No. 62, p. 492.

According to my opinion the treatment ought to be directed in the first place to the central nervous system, to the medulla and the cervical cord, subsequently also to the region of the splanchnics, the dorsal cord, and the thoracic sympathetic; and galvanic treatment of these parts ought to be tried first. You will also not neglect direct treatment of the cervical sympathetic and vagus. Seidel addressed his treatment directly to the region of the kidneys, placing one electrode (which ?) on this region, to the side of the spine, and the other anteriorly, at the same level in the hypochondrium, galvanising each side for 5 minutes with a strong current.

For some cases general faradisation or central galvanisation is to be recommended.

I have myself made a number of investigations in diabetes insipidus, and have treated it perseveringly with a variety of methods, but I cannot express myself as satisfied with the results, which were generally negative. Still I am prepared to make further experiments with electrisation.

X. *DISEASES OF THE ORGANS OF SPECIAL SENSE.*

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LECTURE XXXIII.

Introduction—Diseases of the Visual Apparatus—Electrodiagnosis—Diseases of the Eyelids and Conjunctiva; of the Cornea; of the Iris; of the Lens; of the Vitreous Body; of the Choroid—Diseases of the Retina and of the Optic Nerve -Retinitis Pigmentosa—Papillitis and Papilloretinitis—Optic Neuritis—Cases—Methods of Treatment—Atrophy of the Optic Nerve, Tabetic and Genuine — Cases — Treatment — Amaurosis without Anatomical Cause—Hemianopia—Diseases of the Ocular Muscles—Insufficiency of the Internal Recti—Accommodative Asthenopia—Mydriasis—Nystagmus.

It is with much difficulty and very incompletely that modern electrotherapeutists have been able to bring diseases of the organs of special sense into their domain, although in former days many attempts to cure these diseases were made, and sometimes with considerable success. The blame may be laid partly on the difficulties which, as you know, interfere with the thorough physiological investigation of these organs by means of the electric current; partly on the dread of acting upon such delicate and finely organised structures with an agent which is as powerful as it is in many respects obscure. But the fault lies especially in the fact that the special treatment of the sensory organs and the special practice of electrotherapy are now in different hands. It is true, however, that the intimate relations which exist between the diseases of the nervous system and those of the organs of special sense, and the great importance of the latter for neuropathology, have lately incited neuropathologists and electrotherapeutists to a more thorough study of the sensory organs, and the full importance of electrotherapy is now recognised in such diseases from this point of view. From that of the specialist, however, this cannot be said to be the case to the same extent; it cannot be ignored that in the opinion of oculists, and especially of aurists, electricity is not held in the estimation which it undoubtedly deserves, and that its applicability in various diseases of the higher sensory organs is not yet sufficiently recognised by all specialists. It is to be hoped that this will change in time.

Electrotherapy has, of course, its greatest field of action in the diseases of the organs of sense of nervous origin, but I shall be able to show you, although only briefly, that it may also be employed for other lesions, and sometimes appears to have a great deal to do in their cure.

I shall begin with the *visual apparatus.* The great development which ophthalmology has undergone within the last few years has shown the importance of eye diseases, not only from the point of view of practice, but also from that of the scientific development of pathology. The ophthalmic diseases that have become of the greatest importance in neuropathology are those which affect the actual nerves of special sense, the optic nerve and the retina, as well as those affecting the neuromuscular apparatus in the eye. The great frequency of nervous affections of the eye as premonitory symptoms, accompaniments and sequelæ of so many important diseases of the nervous system and of some general diseases, has led to the special study and the thorough treatment of these affections by neuropathologists.

It is in connection with these points that electricity has been first brought into use, but its share in the treatment of nervous diseases of the eye is still comparatively small, and it is probably considerably undervalued. Its importance in the treatment of eye affections which are not nervous is, however, much less, although much has been investigated and tried in this direction also.

I have already taken occasion to remark (vide Lect. XII., p. 228 et seq.) that the electrodiagnosis of eye diseases still leaves much to be desired—that it is much in need of more thorough study, but that it promises much that is interesting and profitable, and all that is wanted is systematic investigation of the facts.

I need not explain further here which actions of the electric current are most useful in treating eye diseases, or in what way they fulfil the different therapeutical indications. They are identical with those I have fully discussed in the former lectures on the diseases of the central and peripheral nervous system. The stimulating and modifying, but especially the direct and indirect vasomotor and katalytic actions are to be employed here also, according to circumstances and to the forms of disease which may be present. The undoubted connection which exists between the cervical sympathetic and the cervical cord on the one hand and the structures of the orbit with the bulb on the other, as well as the influence which the trigeminus appears to have on the circulatory and nutritive relations of the eye, induce us to take account of these relations in the electrotherapeutic methods. More particulars will be given with the different forms of disease.

We shall discuss them *seriatim*, so far as they are accessible to therapeutic influences by means of the electric current. I will sketch shortly the electrotherapy of the less important diseases, and dwell longer only on the diseases of neurotic origin, referring almost exclusively to my own experiences.

I have very little to say about the *diseases of the lids* and *conjunctiva*. Dutrait treated certain forms of entropion and ektropion, referred by him to atony and atrophy of individual fasciculi of the orbicularis palpebrarum, by careful faradisation of these fasciculi. They were sought out by means of a fine electrode, and those the contraction of which disturbed the normal position of the lid were treated perseveringly for a long time. The facts belong, therefore, to the domain of local muscular paralysis and atrophy.

For *trachoma* Rodolfi has found the dynamo-chemical action of the galvanic current useful. He applies K in the form of a copper button sound to the granulations of the everted eyelid, whilst A (moist sponge electrode) is placed on the lower jaw, the current being from only two of Bunsen's cells. The effect was very satisfactory in some cases, the granulations disappearing after a few sittings, although relapses occurred occasionally. The failures which Arcoleo reports in the same diseases are referred by Rodolfi to his incomplete method. A. C. Smith has also recommended a similar electrolytic treatment of trachoma; he applies the electrodes in the form of suitably bent wires, fixed at a distance of about 5 mm. from each other and connected with two cells, directly to the conjunctiva, from $\frac{1}{2}$ to 1 minute for each lid.

Diseases of the cornea have been most thoroughly treated, as it appears, by Arcoleo, almost exclusively with the faradic current. The positive pole is placed on the nape of the neck or in the hand, and the negative, in the form of a small sponge or camel's hair brush, directly on the conjunctiva and cornea, or applied by means of a large sponge to the closed lids, this being modified according to the form of disease to be treated. Arcoleo has very rarely employed the galvanic current. The sittings should last from 5 to 8 minutes daily. Arcoleo has obtained very good results in this way in *parenchymatous keratitis*, the hair pencil being applied to the conjunctiva and atropine frequently dropped in. The cornea begins to clear even after a few sittings, going on gradually to more or less complete cure. The success in a case of *epithelial keratitis* appears to have been brilliant. He claims to have treated corneal ulcers in the same way with very good effect, and only by touching the base of the ulcer lightly with the hair pencil 2 or 3 times during each sitting. I myself once treated a case of very long standing—whitish opacity of the cornea—for a long time in this manner, without any noteworthy result, which was also the case with all other treatment. In one case of commencing *keratitis* and *neuroparalytic conjunctivitis*, from paresis of the left trigeminus, I have seen decided benefit from the galvanic treatment of the eye (K stabile and labile on the closed lids), (Obs. 132). Brière (quoted by Boucheron, p. 80) cured a parenchymatous keratitis in a few weeks by the application of the galvanic current (4 to 6 cells), and Chvostek treated a pannous keratitis with persevering galvanisation of the sympathetic with splendid effect.

Of the *diseases of the iris*, apart from its nervous affections, only *hypopyon* seems to have often been made the subject of electrotherapeutical experiments. Arcoleo praises specially the faradic treatment, according to his method given above; he applies his fine sponge electrode directly to the lower margin of the cornea, and touches the region of the collection of pus itself three or four times in the course of the sitting; after the sitting atropine is dropped in, and hyperæmia of the conjunctiva follows upon the application. Even on the following day there will be a considerable decrease in the hypopyon; slight degrees of it have even been cured in *one* day, and more severe in from 4 to 7 days (20 cases). Weisflog also has seen good results in five cases of hypopyon from his method (6 to 8 sittings of half an hour daily, with large sponge electrodes on the closed eye), and he reports besides a very acute iritis which was cured by 3 daily faradisations of an hour each.

Among the *diseases of the lens*, *cataract* has lately been subjected to electrotherapeutic applications. Neftel has called forth no little excitement in ophthalmological circles by the communication that in two cases of indubitable incipient cataract he has removed every symptom of cataract by methodical galvanic treatment, and restored the sight completely. However, upon a sharp criticism of his report by Hirschberg, Neftel admitted that in both cases the opacity of the lens visible by means of the ophthalmoscope had not quite disappeared, and he endeavoured to explain the undoubted improvement of the sight in both cases by the removal of a molecular opacity, not discernible by means of ophthalmoscopic investigation. He professes to believe that some influence on the opacity may be obtained by galvanic treatment in mature cataract also, but not to a very great extent.

The question is therefore quite in its infancy; but its considerable importance certainly justifies further careful investigations in this direction, which must of course be directed first and principally to *commencing* cataract, all the more that by means of the observations of the most trustworthy ophthalmologists the occasional standing still and even retrogression of incipient cataract is firmly established (vide O. Becker, 'Krankh. d. Linse,' in Gräfe-Sämisch's *Handb. d. Augenheilk.*, v. p. 308).

The method employed by Neftel is the following: A stabile to the nape of the neck, K stabile and labile on the closed eyes. Begin with 5 cells; then pass the current in the opposite direction; the same procedure to be repeated, rising in intensity 1 cell higher up to 15 cells. The whole length of the sitting to be 10 to 15 minutes, at first daily and afterwards less frequently.

In *diseases of the vitreous body* the electric current has been employed, not without success, especially for opacities. These may originate from very different morbid processes, and may have a correspondingly different pathological significance. Extravasations of blood, inflammatory products, degenerative processes, pus, cicatricial formations, &c., may here come into play, and even this fragmentary enumeration shows that certain forms of opacity may be accessible to the action of the electric current, although not all; for some yield quickly, others only slowly, to the katalytic action of the current.

Giraud-Teulon appears to have most fully gone into the galvanic treatment of these forms of disease. He has lately stated in a preliminary communication, that the galvanic current is the most effectual and also the most rapid remedy for most vitreous opacities; and Onimus has further published a number of experiments in the thesis of Carnus, also in a favourable sense, but the methods of the two are not identical. Boucheron also communicates some observations, and Le Fort has recommended his methods of continuous weak galvanic currents for these opacities.

According to the observations published by these authors, there appears to be no doubt that a certain influence is exercised by the galvanic current on vitreous opacities, and that by its employment in not a few cases, which have long been treated in vain by other remedies, a remarkably rapid and more or less complete removal of these abnormalities may be effected. These observations invite us to further, and especially more thorough, investigations.

The methods employed by the various writers are certainly very different; for while Le Fort places the electrodes, connected with only two weak cells, on the temples, and allows them to remain there day and night, Giraud-Teulon applies the anode of 8 or 10 Daniel's cells to the closed lids, the kathode behind the ear, for 2 or 4 minutes. Onimus places the kathode on the closed lids and the anode on the sympathetic of the same side, with 8 to 10 cells stabile, for from 2 to 5 minutes; while others have simply applied the poles to the forehead and the nape, and all have seen good results. From this we may easily see that not much depends upon the direction of the current or upon which pole is applied to the eye, but that it is only essential to let the current flow through the eye; and this agrees with our general views as to the methods of attaining katalytic action. For further trials I would recommend that the current should be passed from the closed lids to the nape of the neck, with suitable sponge electrodes, and with reversals of the current, either so that in each sitting first A and then K should act upon the eye, or so that in one sitting only A and in the next only K should be employed. The currents should be weak (4 to 10 Stöhrer's cells), the action stabile, and the duration of the sittings 2 to 5 minutes. It can hardly be stated *à priori* whether it would be advisable to include the cervical sympathetic in the treatment, by the application of the indifferent pole to the superior ganglion; direct investigations must decide this point.

Dor gives some very encouraging results with regard to *diseases of the choroid.* The most suitable cases for electrical treatment are said to be those where, after a disseminated choroiditis, atrophic changes in the retina, with scotoma, &c., develope after months or years, cases with numerous collections of pigment, plastic exudations, and patches of atrophy. He treats them with the galvanic current passed transversely through the temples, or, if the disease is one-sided, from the supra-orbital ridge to the mastoid process of the same side.

140. *Observation by Dor. Chronic Retinochoroiditis.*—A gentleman, aged 36. Ill for 2 years. Treated in vain with all sorts of reme-

dies (blood-letting, mercury, iodide of potassium, sweating, setons, baths, &c.); had to be led about. Diagnosis: Disseminated choroiditis with numerous collections of pigment and consequent alteration of the retina; pupil somewhat reddish, sharply defined. Large central scotoma on both sides. V. both sides, No. C. in the immediate neighbourhood. First treatment with Heurteloup's (artificial leech), causing improvement to $\frac{1}{12}$ (with excentric fixation), no further. Galvanic treatment. After 3 weeks all the letters in VII. read, and some in VI.; 5 months' pause; letters in VII. read. Strychnia administered for 8 days without improvement. Galvanic current again; after 2 days letters in VI. read; after 8 days some in IV.; after 3 weeks all the letters in IV., and after another 3 weeks all the letters in III.; the improvement, however, being only in the right eye and consisting especially in the steady diminution of the scotoma. Central vision possible from May 29 with No. XL.; on July 8, No. XX.; on July 30, No. VI.; on August 24, No. V. Improvement in the first affected left eye only after 45 days of electrical treatment, on May 29, going on from that time; on June 18 (excentric), No. XV.; on July 8, No. X.; on July 30, No. VI.; August 24, No. VI.; the central scotoma considerably diminished.

Diseases of the retina and of the optic nerve itself are, however, by far the most important for electrotherapeutists, partly on account of their frequency and their pathological significance and partly on account of the repeated success which the electric current has had in these very diseases, especially in simple inflammatory diseases and their sequences, and in mere disturbances of function without perceptible anatomical changes, though not so much in primary degeneration and atrophy.

In *retinitis pigmentosa* Dor has had great success in several cases with his galvanic method described above, and he invites further trials of it. Neftel also reports one good result.

In *papillitis* and *papilloretinitis*, which occur in so many diseases inside the cranium, especially in tumours and meningitis, and which are generally called 'choked disk,' there is not much to be expected from electrical treatment (although Driver claims to have frequently seen good results from galvanisation of the sympathetic in this symptomatic neuroretinitis) so long as the process is still acute and the fundamental disease not cured; and there is not much to be done for this fundamental disease by means of the electric current. We may expect, however—and there are some instances of its having occurred—that the electric current will prove very useful in the subsequent stages of the disease, after the cause has run its course or has been arrested, and that it may induce a decided improvement in the sight. The treatment is the same as in any case of optic neuritis with secondary atrophy.

Optic neuritis, in its various forms and issues, is the most suitable object for electric treatment among all the anatomical diseases of the optic nerve.

Pflüger has seen a number of good, and sometimes brilliant, results from galvanic treatment in optic neuritis and in atrophy of the optic nerve, but he does not specify his method more particularly.

Leber advises treatment of the sympathetic in the congenital affections of the optic nerve described by him, and designated 'neuritis retrobulbaris,' on the grounds of the observation already mentioned (vide Obs. 49, p. 418). In several other cases of the same kind, however, this good result has been wanting.

I have myself obtained a very satisfactory result from repeated galvanic treatment in a case of descending optic neuritis with transverse dorsal myelitis and permanent amblyopia, with atrophy of the optic nerve on ophthalmoscopic examination.

141. *Personal Observation. Optic Neuritis and Subacute Dorsal Myelitis.*—A gentleman, aged 52. Somewhat sudden blindness in February 1877, first in the left eye, with recovery of sight after a few weeks; soon after, a similar affection in the right eye, which also recovered; after a few weeks relapse in both eyes, going on to complete amaurosis. On ophthalmoscopic examination distinct optic neuritis with already commencing atrophy. Gradual improvement from the middle of June. From the end of June symptoms of transverse dorsal myelitis, leading, by the end of July, to complete paraplegia, with anæsthesia, paralysis of the bladder, increased cutaneous and tendon reflexes, &c., into which it is not necessary here to enter further. From the beginning of August 1877 some improvement in these symptoms also; by the end of September ability to walk a few

steps. Slow and gradual advance of improvement, even in the eyes. In summer 1878 a course of baths at Nauheim, with good results.

On November 12, 1878, the eyes having remained stationary for a long time, commencement of a course of galvanic treatment for them. Condition on that day (Prof. O. Becker): Pupils somewhat contracted, reacting to light; small amount of myopia in both eyes. R.E. V. $\frac{6}{60}$; L.E. somewhat less, V. $\frac{6}{\infty}$. With + 3 J. No. 3 with the right eye, No. 6 with the left, slowly recognised in single words. Both eyes blind for red and green. Ophthalmoscopic examination: Atrophy of the optic nerves with slight atrophic excavation, more pronounced on the left. Method of treatment: 4 to 6 cells Stöhrer, transversely through the temples, 6 to 8 cells from the nape to the eyes, for 3 or 4 minutes daily (besides galvanisation of the back, with 10 to 12 cells, ascending and descending stabile, for 2 or 3 minutes). On December 10 both eyes decidedly better. R. V. $\frac{6}{36}$; L. V. $\frac{6}{60}$. J. Nos. 3 and 6 read with +3. On February 4, 1879, R. V. $\frac{6}{18}$, L. V. $\frac{6}{36}$ to $\frac{6}{24}$. On March 4 R. V. $\frac{6}{18}$ to $\frac{6}{12}$, L. V. $\frac{6}{24}$ to $\frac{6}{18}$. J. No. 3 read with +3, and single words of No. 2; with +4 and +5 newspaper read fluently. Cessation of treatment. No improvement from subsequent repetition of similar treatment; patient able to write and to read ordinary print.

Rumpf has recently cured, by means of the faradic brush, a case belonging to the same category.

142. *Observation by Rumpf. Optic Neuritis with Transverse Myelitis.*—A lady, aged 37. Ill for about 2 years. Paresis of the lower extremities, with swaying on closure of the eyes; decided diminution of the motor power of the legs, paræsthesia; diminution of sensibility in the legs, girdle feeling, increased tendon reflex, constipation of the bowels, incontinence of urine. Diminution of vision (J. No. 14 read with difficulty). Ophthalmoscopically (Mooren) condition about midway between congestion of the disk and neuritis; swelling, opacity, intense injection of the disk, dilatation of the arteries and veins. Treatment with the faradic brush: energetic and slow brushing over the skin of the chest, back, and upper extremities. Result very good; injection of the optic nerve less on the 3rd day, then improvement in the swelling of the disk; J. No. 7 read on the 6th day. After 28 sittings (the back being afterwards galvanised) disappearance of all the symptoms of myelitis, J. No. 3 read, ophthalmoscopic appearances normal.

The following observation of secondary atrophy caused by optic neuritis belongs to the same category.

143. *Personal Observation. Optic Neuritis with Atrophy of the Optic Nerve.*—A bank attendant, aged 21. Came under treatment on December 2, 1880, on account of amblyopia, which had existed for some months and had developed somewhat rapidly. Ophthalmoscopic appearance of optic neuritis, with transition into atrophy; marked amblyopia, inability to walk without guidance or to count fingers; considerable limitation of the field of vision. Suspicion of tuberculosis raised by the eye doctors, not confirmed by the patient, although he was very delicate. Two sisters of his mother similarly blind in youth. Treatment: Ext. nuc. vom. and galvanisation; 6 cells transversely through the temples, 6 to 8 cells from the nape (A) to the closed lids (K stabile and labile), and consequently also to the cervical sympathetic, for 2 or 3 minutes daily. On January 10, 1881, distinct improvement in the sight; on Snellen's tables the letters on D=9 recognised quite well, and D=6 partly, with the left eye; but with the right D=9 only partly. Colours: Green very uncertain, red rather so, blue and yellow distinct, but not quite correct. Ophthalmoscopic condition better; hyperæmia and swelling less, particularly on the left; disk and vessels clearer. On January 20 great improvement, especially on the left. L., D=3 read quite well; R., on the other hand, D=9 still with difficulty. On January 30 L., D=1 spelt out with difficulty; R., no improvement. On February 2 commencement of injections of strychnia. On February 27 L., D=1 read quite easily; R., a few letters of D=4; a few words read with the left eye; field of vision still very small, but guidance in the street no longer necessary. On March 24 a journey into Switzerland. Return two months later, again improved. R., now D=1 quite well; L., even D=0·60 well and D=0·50 a few letters.

I have still some notes—unfortunately not complete ones—of several other cases, in which galvanic treatment proved itself useful to a certain extent at least, while I certainly have had to note down a great number of negative results. In Benedikt's writings there are also related many successes in neuroretinitis and in optic neuritis.

The method of treatment will easily be inferred from the prominent indications; we have to do chiefly with katalytic actions, and we must therefore use stabile currents principally, and apply them directly to the eye and to the optic nerve. In the first stages the anode is to be applied to the eye (although not to be used exclusively); later, if the process has turned more to atrophy, recourse to the action of the kathode is to be preferred; but from experience, as well as for anatomical and physiological reasons, the simultaneous galvanisation of the sympathetic is to be tried, which will act at the same time on the cervical cord. In general, large electrodes, weak currents, and short sittings (not more than 2 to 5 minutes) are to be recommended; and the treatment must generally be continued for a long time.

The details of the application, then (independently of the treatment of the fundamental affection, if this has to be undertaken), are as follows:—

First, transverse passage of the current through the temples, in order to affect the optic nerve in the orbit, with reversals of the current; and then longitudinal passage from the nape to the closed lids. When neuritis predominates, the anode, principally, must be placed on the eye, and the kathode only temporarily, stabile; but when atrophy has come on, the kathode chiefly on the eye, after the anode has acted for a little, stabile and to a small degree labile. Finally, you must try galvanisation of the sympathetic, after the usual method, in which you must decide by special trials whether the kathode shall always be placed on the superior ganglion, or whether the anode is not sometimes more effectual.

Numerous observations show that with this procedure results may be obtained which may very well compete with those of the strychnine treatment in these diseases. It is frequently seen that the results are much better as tested by the acuteness of vision than by the ophthalmoscopic appearances, for a most typical white atrophy of the optic nerve may be found to exist, while at the same time vision and sense of colour have again become fairly good.

But the results of electric as of any other treatment are much less satisfactory in *primary* atrophy of the optic nerve, in which a prodromal stage of inflammation has not been observed, but in which we have had to do from the beginning with degeneration of the nerve. These are the worst forms of optic disease, which stand still or even retrogress only in the rarest cases ; still treatment is not entirely useless even here, and other experiences show it to be our duty not to be discouraged in our therapeutical endeavours even under such unsatisfactory conditions.

This is especially the case in atrophy of the optic nerve in tabes dorsalis or locomotor ataxy. It is extremely important, because it often occurs very early among the symptoms of this disease, and it may, apparently, precede the appearance of the other symptoms by many years. But this is not very often the case, and, as we have recently learned to recognise the earliest beginnings of locomotor ataxy, we shall often give the affection of the optic nerve its proper significance from the discovery, on careful examination, of the presence of lancinating pains, reflex rigidity of the pupil, slight analgesia, and especially the failure of the tendon reactions. The disease shows itself by diminution of vision and of the sense of colour, limitation of the field of vision with angular centripetal encroachments, and progressive amblyopia, with the characteristic ophthalmoscopic appearances.

It is of course very important that the disease should come under treatment at the very first beginning, because it is only then that there is any hope of retaining the power of vision at all. But even here the results are to a great extent doubtful or even negative, and I have repeatedly seen the disease advance steadily to amaurosis, in spite of continued treatment.

Almost all observers agree in stating that the results of electric treatment in tabetic atrophy of the optic nerve are nearly always negative ; but individual cases nevertheless occur which show that a standstill or even a more or less considerable improvement may be attained, just as we find in the simultaneous affection of the posterior columns of the cord. I have myself treated such a case, but, unfortunately, I possess no notes of it. It was the case of an officer, aged 46, who had suffered for 12 years from the preliminary symptoms of locomotor ataxy, and for 2½ years from atrophy of the optic nerve, with considerable limitation of the field of vision in both eyes (Prof. O. Becker). Four weeks' galvanic treatment caused a considerable extension of the field of vision, and the central vision also, which was not notably diminished at the commencement of the treatment, had become better in both eyes. I have not had any more news of the patient since. Compare with this case Obs. 26, given above, in which, however, the diagnosis of ataxia was not so certain.

The method of treatment is exactly the same as has been already given for neuritic atrophy. But it is important in all such cases that the spinal cord should be treated at the same time, and certain physiological data are given for this treatment in the experimental investigations of v. Forster and Rieger. Do not neglect, therefore, in such cases the regular treatment of the spinal cord.

The results are somewhat more favourable in the not very rare *genuine atrophy of the optic nerve*, which is developed in some people from unknown causes, without any appreciable connection with spinal or cerebral diseases, and is exactly analogous to the tabetic 'white atrophy' in its functional disturbance and ophthalmoscopic appearance. A few very good cures by galvanic treatment occur in this form (see the already mentioned observation of Donald Fraser, Obs. 50, p. 418).

144. *Observation by Driver. Atrophy of the Optic Nerves.*—A teacher, aged 24. Suffered for years from the eyes, amblyopia; repeatedly treated by the best authorities without result. On examination well-marked atrophy of both optic nerves found, with shallow excavation; vessels as thin as a hair, nystagmus-like movements of the bulb. Vision-testing: R., fingers seen at 4 feet; L., only at 3 feet. Limitation of the field of vision; Daltonism. Strychnine injections for 3 weeks; no improvement, but a standstill of the disease. Then galvanic treatment; after 2 months fingers counted at 20 feet. Treatment continued at home. Snellen No. 8 read a year after, and all colours recognised. Ophthalmoscopic appearances decidedly improved; vessels larger.

145. *Observation by Driver. Incipient Atrophy of the Optic Nerve.*—A woman, aged 45. For a long time amaurotic in the left eye; for a short time a cloud noticed before the right eye. Otherwise perfectly healthy. Ophthalmoscopically L. typical atrophy of the optic nerve, R. disk somewhat whiter, and vessels somewhat smaller than normal. V. $\frac{20}{50}$; field of vision and sense of colour normal. After 3 weeks of galvanic treatment R.V. $\frac{20}{20}$, disappearance of cloudi-

ness, ophthalmoscopic appearance again normal. L., fingers counted for 2 feet upwards and outwards. After 6 months a falling-back again; R., cloudiness again present, V. $\frac{20}{30}$. Complete cure after 12 days of galvanic treatment.

146. *Personal Observation. Incipient Atrophy of the Optic Nerves.*—A man, aged 48. A drinker; often exposed to cold while in a drunken condition. Diminution of vision for the last 8 months, with frequent pains in the head. Otherwise healthy. Sent to me by Prof. O. Becker for galvanic treatment, with the following ophthalmic report: R., V. $\frac{6}{60}$ (more distinct but not more seen with -1); L., V. $=\frac{6}{60}$ (more distinct with $-1{\cdot}5$). J. No. 13 read at 7 feet with both eyes. Eyeballs normally tense, reaction of pupils normal, refractive media clear. Disk on each side paler than normal, and not sharply defined; vessels tolerably well filled. Field of vision and colours good. Galvanic treatment: 8 to 10 cells transversely through the temples and through the mastoid processes; 8 to 10 cells from the nape to the eyelids, with reversal of the current. Even after a few days report of considerable improvement; head more clear, disappearance of pain, improvement in vision. After 14 days' treatment examination showed R. V. $=\frac{6}{18}$, L. V. $=\frac{6}{18}$; J. No. 6 read with both eyes. Further notes unfortunately wanting.

147. *Observation by Dor. White Atrophy of the Optic Nerves.*—A lady from the South of France, unable to walk alone. Sn. LXX. a few letters seen with the greatest difficulty, as close to the eyes as possible; became affected 2 years ago, first on the right side, then on the left. On both sides white atrophy of the optic nerves. Frequent pain in the head. Improvement from artificial leeches and iodide of potassium, so that Sn. XX. can be read; no further improvement in spite of mercury, pot. iod., &c. Then employment of faradic current; after 8 days Sn. XV., after 14 days one letter in Sn. VIII., after 3 weeks Sn. VI.; no more improvement. Patient again under treatment 7 years later; vision again diminished, but only to $\frac{1}{\text{XX.}}$. Galvanic current now employed (Oct. 6, 1871). On October 14 V. $=\frac{1}{\text{XV.}}$; on October 17 $\frac{1}{\text{XII.}}$; on October 21 $\frac{1}{\text{X.}}$; and on October 24 $\frac{1}{\text{VIII.}}$. Patient could not remain longer, but the benefit continued.

148. *Observation by Dor. White Atrophy of the Right Optic Nerve.*—A gentleman, aged 46. Right eye affected for 6 weeks; distinct appearance of white atrophy. V. $=\frac{20}{\text{C.}}$; field of vision much

contracted. Galvanic treatment: after 8 days $V. = \frac{20}{C.}$, but great enlargement of field of vision; after 14 days $V. = \frac{17}{LXX.}$; field of vision again enlarged. Patient went away, but continued the treatment at home, and wrote that the eye steadily improved, until finally the treatment was discontinued.

There cannot be the least doubt, after this little selection of cases, and especially after the very careful and numerous observations of Dor, that a considerable curative power must be attributed to the galvanic current in these diseases of the optic nerve, which are otherwise so hopeless and which occur in the form of a so called white atrophy. Dor states, on the authority of a very imposing number of observations, that the number of true and considerable improvements may be reckoned at 40 to 50 per cent. at least of these cases, and that is decidedly a satisfactory result. You will certainly often be able only to induce a partial cure, an improvement of the vision, or an extension of the field of vision, but when you consider of what value even a moderate improvement is to these unfortunate patients, you will not grudge the time and trouble which must be expended on a trial of the galvanic current.

The method of treatment to be recommended is exactly the same as I described to you before for secondary atrophy. Here, with the increased age of the processes, the action of the kathode on the eye ought to be increasingly intense.

In *amblyopia and amaurosis without anatomical change* the electric current also appears to be of beneficial effect. The various writers, however, express themselves very differently about the matter, Driver having seen hardly any results, whilst Boucheron, Secondi, Arcoleo, Seely, and others report very favourably of it. A great deal of observation and experience is evidently wanting here, and the strychnine treatment, which has so rapidly become a favourite, has stood in the way of the proper application of the galvanic current.

We have here to do with amblyopia from nicotin, alcohol, and lead poisoning, with spontaneous and traumatic anæsthesia of the retina, some of the hysterical amauroses and amblyopias, with amblyopia ex anopsia, and with hemeralopia. A few favourable cases have occurred.

149. *Observation by Boucheron. Central Scotoma.*—A jeweller remarked some disturbance of vision in the left eye on waking, which afterwards increased. Central scotoma was present; only J. No. 19 could be read Ophthalmoscopic appearances negative (Sichel, jun.) On the eighth day application of weak permanent galvanic current, 2 elements Trouvé, for 6 hours; J. No. 8 spelt out. Daily repetition of the application; after 4 days J. No. 1 read at 15 centimetres. Complete cure.

150. *Observation by Boucheron. Convergent Strabismus. Marked Amblyopia of One Eye.*—A lad, aged 17. Seized with a great degree of convergent strabismus and nystagmus in January 1875; operated on both sides with good results. In February 1875 great amblyopia of the left eye; Sn. L. read with difficulty at 10 centimetres. Application of weak continuous currents of 2 cells, Trouvé, A on the forehead, K on the nape, during the whole night, and sometimes also for some hours during the day. Sn. No. XXX. read after 10 days, No. XX. after 8 days more, and No. XV. after other 4 days. Treatment discontinued till March 2; No. XV. still read. Treatment resumed; on March 8 No. XII. and even No. X. read. Discharged.

151. *Observation by Secondi* (*through Boucheron*). *Traumatic Anæsthesia of the Retina.*—A girl, aged 16. Received a contusion of the eye by a hard substance; no injury except ecchymosis of the bulbar conjunctiva; $V.=\frac{1}{4}$; vision diminished immediately after the accident; pupil less movable than the healthy one. Galvanic treatment: K labile on the eyelids, A in the nape. Improvement from the first sitting onwards; cure after 3 sittings.

Arcoleo reports very good cures in hemeralopia; he distinguishes two forms, one organic, with visible anatomical changes, and one functional. The electric current is of service in the latter form especially; the results seem to be very brilliant, 'so to speak unfailing,' but even in some of the organic forms considerable improvement occurs. He employs only the faradic current, K on the closed lids, A on the nape, for 5 or 10 minutes, and the cure is sometimes effected after one sitting, but generally there is only improvement after 2 or 4 sittings.

For these diseases also, therefore, quite apart from theoretical considerations, there is already sufficient experimental material to justify further researches. In most cases preference ought to be given to the galvanic treatment, according to the method already described; but Arcoleo's experiences in hemeralopia indicate very plainly the value of the faradic current also, in that form of disease at least.

Hemianopia, which has lately been the subject of interesting physiological and pathological debates, may also be the subject of electrical treatment. I have a case at present under observation occurring simultaneously with left-sided hemiplegia, and the result of apoplexy, in which the electrical examination shows an undoubted light picture in both eyes, presenting only the half of a circular disk and corresponding exactly to the form of the remaining field of vision. As hemianopia, at all events in the homonymous lateral form, never depends on disease of the eye, but always on disease of the optic tract or of the brain itself, you will intermit the direct electric treatment of the eye and confine yourself to that of the fundamental affection, according to the methods which you know already.

A few words remain still to be said about *diseases of the ocular muscles and their nerves*. We have already discussed the most important and the most frequent of these—paralysis—in a former lecture (Lecture XXIII., p. 445). I will only say a few words here about the weakness of individual muscles and muscular apparatus, which belong almost entirely to the domain of the oculist, and principally about the *muscular asthenopia* which is so frequent, which is caused by insufficiency of the internal recti, and in which Landsberg and Driver, as well as Seely, have had great success with the galvanic current. We have to do with suitable treatment of the paresis of the internal recti, with regard to which I would refer to the methods already given (p. 448). My own experiences with this affection are not particularly satisfactory, although certainly they are not very numerous, and Macher has also had negative results.

Electricity has also been recommended on various sides (Arcoleo, Driver) for *accommodative asthenopia*, and also for *mydriasis*, but the cure has often to be long waited for (Erb).

Disturbances in the pupillary reflexes (*reflex rigidity*, Erb) I have, as I said before, as yet treated in vain galvanically.

There is not much to say about the *convulsive diseases* which affect the eye. I have already said all that is necessary about *blepharospasmus* (p. 564). For acquired *nystagmus* Soetlin and Nieden have successfully employed the galvanic current (stabile from the mastoid process to the eye for 1 or 2 minutes daily). There is not much to be done for congenital nystagmus or for nystagmus in multiple sclerosis, hereditary ataxia, &c.

From these statements, gentlemen, you will see that not a small, and certainly not a prospectless, curative action falls to the share of the electric current in the region of ophthalmic diseases. Further investigations are much to be desired, not only in the interests of ophthalmology, but also specially in those of electrotherapeutics, because here we have the advantage of being able to observe the anatomical changes, and the influence of the remedy upon them directly and without any intervention, to determine the functional disturbances which may be present in the most exact manner, to control the improvement which takes place by various expedients, and so to collect therapeutical experiences with an exactitude which could hardly be reached in any other domain of pathology. With the large eye clinics which are now established everywhere, amply furnished with remedies and with a superfluity of material, it would certainly be a very grateful task for a young investigator to undertake the systematic study and working out of electrotherapeutics in eye diseases. Besides the study of electrodiagnosis, to the importance of which I have already referred, my advice would be to attend specially to the various forms of optic neuritis and neuroretinitis, as well as atrophy of the optic nerve, opacity of the vitreous, and commencing cataract, as being those diseases which, according to past experience, promise most successes, as well as claim special attention on account of their frequency and danger. May there soon be found workers for this field of therapeutic investigation!

LECTURE XXXIV.

Diseases of the Auditory Apparatus—Introduction—Dryness of the Auditory Meatus—Opacity of the Tympanic Membrane—Diseases of the Nervous Auditory Apparatus—Nervous Buzzing in the Ears—Its Relations to Galvanic Reaction — Electrodiagnosis — Therapeutical Indications — Establishment of the Method of Treatment—Cases—Rules for Treatment—Special Procedure in Individual Cases—General Rules and Technical Remarks—Results—Nervous Deafness—Cases—Methods of Treatment—Deaf Mutism—Menière's Disease—Neuroses of the Nerves of Taste—Ageusis—Neuroses of the Olfactory Nerves—Anosmia and its Treatment.

I come now to the *auditory apparatus.* For many years numerous attempts have been made to bring relief to those suffering from deafness, by the use of electric currents. Many of these attempts have not been in vain, and several of the cures reported were undoubtedly due to the employment of electricity. But the position of auditory science, as well as that of electrotherapeutics, has not at all times allowed of really exact and scientific advances.

These date from Brenner's splendid labours, which have earned for the galvanic current an important and unassailable position in the region of auditory science. All aurists do not yet seem to have arrived at the true understanding of the matter.

It is principally and almost entirely nervous auditory affections which have as yet been subjected to electrical treatment, but nervous auditory affections are frequent; the labyrinth and the auditory nerve are often primarily diseased, and still oftener disturbances of the nervous apparatus supervene on diseases of the conductive mechanism. But the troublesome and annoying symptom of singing in the ears is especially frequent, being in some cases purely nervous in origin, while in others it cannot at all, or only in part, be referred to nervous diseases. Every expert knows how difficult this symptom often is to remove, and how helpless auditory science is against it, especially with its favourite 'mechanical' treatment. But it is just in this widespread and troublesome affection that the electric and especially the galvanic current has very often proved successful, often, with the removal of the subjective noises, relieving the accompanying deafness. The results are sometimes even brilliant, after all other remedies have been tried in vain. And these results are not merely dependent upon chance; they progress on the grounds of methodical diagnostic investigation and the scientific determination of therapeutical indications based upon it. This is proved by numerous unassailable facts.

It is principally Brenner's merit, on the ground of his electrodiagnostic labours on the auditory nerve and his many careful therapeutical observations, to have developed these indications, established the several methods of treatment, and proved their efficiency; and this merit is not to be lessened by the deficient understanding and the grudging opposition of certain aurists, influential though they may be, who would willingly suppress the valuable facts.

But, besides nervous affections, some other pathological conditions of the organ of hearing have been subjected to the influence of electric currents, with good results; I shall mention them briefly.

1. *Abnormal dryness of the external meatus*, combined with a troublesome feeling of cold, heaviness, and numbness of the whole ear, and occasioned by deficient secretion of wax, occurs in many old auditory affections. The galvanic current, especially if it is conducted by means of suitable electrodes into the meatus itself, filled with water, generally removes this feeling quickly and effectually, according to the experience of Brenner and Hagen; probably by acting on the blood vessels and the secreting glands. The meatus becomes supple and moist again, the secretion of wax is renewed, and the normal sensation in the parts returns.

2. *Opacities of the tympanic membrane*, which are known to be remarkably frequent, always depend upon the deposit of abnormal products, which may be very various in kind. The frequent observation that an active congestion of the tympanum may be caused by the action of galvanic currents on the ear, showing itself by a great amount of injection in the neighbourhood of the manubrium of the malleus, suggested to Brenner that this might be utilised for the absorption of certain opacities of the tympanum. Experience has

fully confirmed his idea, and Hagen has communicated a number of similar observations. The proceeding consists here also in passing an auditory electrode into the meatus, which is filled with water, and employing galvanic currents with reversals, so that both poles may act alternately. Great perseverance is generally required in this treatment, especially when it is a case of very old opacity. But Hagen has seen the opacity disappear, or be very much lessened, in several cases, after from 12 to 20 sittings, and Hedinger saw similar results.

This experience would suggest (but, so far as I know, it has not yet been followed up) that it might be possible in this way to exert a favourable influence on morbid deposits in the tympanic cavity, sclerotic changes in its mucous membrane, &c. But electrotherapeutists have no experience to guide them in the matter.

3. *Diseases of the nervous apparatus itself.*—Among these the one which is of by far the greatest practical importance is the *subjective noises*, nervous buzzing in the ear.

These are very frequent; they are extremely troublesome and depressing to the patient, disturbing his sleep and his spirits, are combined with unpleasant sensations in the head, diminish his desire and his power to work, and are generally found much harder to bear than the difficulty of hearing, or even absolute deafness, which generally accompanies them. At the same time they are often not to be reached by any treatment; and air douches and catheterisation, derivatives, narcotics and nervine tonics, air and water cures, &c., may be employed for months and years in vain. There is, therefore, no doubt as to their great practical importance, and the discovery of a further and a valuable remedy for this obstinate and severe affection in the galvanic current is to be greeted with double satisfaction.

I have already sufficiently shown (Lecture XII., p. 236 et seq.) the great importance of the galvanic current for the accurate diagnosis of this subjective feeling. It has been shown that, in cases of subjective noises in the ear, very different results of the galvanic examination may manifest themselves. Most frequently there is simple galvanic hyperæsthesia, often going as far as 'paradoxical reaction;' or there may be hyperæsthesia with various anomalies of the normal formula up to a complete reversal of it, or simple reversal of the normal formula without hyperæsthesia, &c. But there are also many cases in which the galvanic examination detects no anomalies of reaction of the auditory nerve, and so remains void of result in that direction. On the other hand it has been shown that the galvanic current has often a direct, modifying influence on the singing, on the subjective noises; and that in a number of cases the buzzing is diminished or even entirely removed by the action of the current, certain excitations doing this while others increase it. It is generally AC and AD, and to a much less extent KO, which have this direct muffling effect upon the buzzing (as in nearly all cases of simple galvanic hyperæsthesia); but it sometimes happens that KC and KD also restrain the noises, as especially in hyperæsthesia with reversal of the normal formula, and now and then even with a qualitatively normal formula. There is another set of cases, again, in which the buzzing is not influenced in any way, either increased or diminished, by the current; and, lastly, there are often certain mixed forms, with two or more noises, in which one or other of these noises is lessened or removed by the current (generally AD), while the others remain entirely unaffected. This shows the variety in the origin of these noises, which has long been placed beyond a doubt on other grounds.

In practice it is, of course, most important to decide whether the noises owe their origin to an implication of the *nervous* auditory apparatus in the disease, i.e. whether they are nervous in origin or not. Unfortunately the material which is at our disposal for deciding these urgent and difficult problems is not yet sufficient. Still we may select a few laws which may serve as guides and data to further investigations.

If it can be shown that, besides the subjective auditory noises, distinct anomalies of the galvanic irritability of the nervous auditory apparatus are present (hyperæsthesia, qualitative changes, &c.)—whether there are any grosser changes in the conductive apparatus or not—it may at least be surmised that the noise has something to do with the disease of the nerves, that it is altogether or in part caused by it. But this surmise becomes the greatest probability if a distinct, modifying influence can be seen to be exerted by the galvanic current on the singing—if it is increased by some stimuli and diminished or completely silenced by others—especially if this is done by AD; and such cases will present a certain chance of success from therapeutical treatment.

But, on the other hand, the nervous nature of a subjective noise becomes very unlikely if no anomalies can be found in the galvanic irritability of the auditory apparatus, or if no modifying influence can be exerted on the buzzing by the galvanic current. But the possibility of a nervous origin is by no means entirely excluded in such a case, and although there will also be less chance of therapeutical success, still it is only therapeutical experiment which can finally decide on its curability or incurability by means of the galvanic current. This is not unimportant in practice.

In the treatment of these affections the results of the galvano-diagnostic examination has an importance which it does not possess anywhere else, and there is not merely a special charm in the clearness and exactitude in which the therapeutical indications and results of the investigation clothe themselves, but the facts which are discovered here are of the very greatest interest for electrotherapeutics in general, and it is just in this that the great importance of Brenner's investigations lies.

The establishment of the methods of treatment is carried out here—at first at least—entirely on the grounds of the reaction formula discovered by the examination, with reference to the modifying action of the current upon the buzzing, which may have been discovered at the same time. This rule may be applied, almost without exception, to all simple and uncomplicated cases of hyperæsthesia with buzzing in the ears. It is, perhaps, premature to devote our attention to the restoration of the normal formula as the direct aim of our treatment, and to arrange our therapeutical remedies and operations really for this end—to diminish abnormal and excessive irritability, to increase that quality where it is diminished, to restore what has been entirely lost, and to throw off what has been newly formed. However enticing this may appear, and however promising the beginnings of this proceeding may be, the whole is still too uncertain to be made entirely the foundation of our therapeutical method. Experience—the immediate effect on the noises themselves—must always be our safest guide in the choice of our methods of cure.

And experience has up to now spoken very strongly in favour of Brenner's discoveries; for diagnostic inferences, therapeutic indications, and final results have displayed a wonderful exactitude in many cases, but of course not in all. That there should be many failures in such severe, obstinate, and generally also long-standing affections will not surprise anyone who is at all familiar with the subject, and particularly anyone who knows how many more failures there have been with other methods of treatment.

But the list of cases is now so rich in undoubted and remarkable successes that the great practical value of electro-otology is established beyond all doubt. Let me quote some proofs of this.

152. *Observation by Brenner. Simple Galvanic Hyperæsthesia with Singing in the Ears.*—A student, aged 23. Difficulty of hearing and constant singing of the most severe kind in both ears, in consequence of long-standing catarrh of the middle ear. Great depression of spirits in consequence, and disturbance in work. Ticking of a watch heard on the left side at 1 inch, on the right at 2 inches; tympanum thickened, very opaque; light spot very small on the right side, absent on the left; Eustachian tube clear on both sides; repeated treatment by aurists without result. Successful electrical treatment of the buzzing a few months ago; relapse from mental over-work and emotional excitement. Galvanic examination gave on both sides, with very weak currents—

KCK''	violent ringing.
KDK	∞.
KO	ringing silenced for a time, gradually becoming stronger again.
AC	ringing disappeared suddenly and completely.
AD	ringing still absent.
AOK' >	ringing returned with increased violence.

For the purpose of treatment the ringing was silenced in each ear by means of AD (K being in the hand); then the strength of the current was gradually diminished by the help of the rheostat, and the circuit finally opened by withdrawing the K from the hand very slowly; the buzzing had then entirely disappeared. After two more sittings permanent removal of the buzzing; watch-tick heard on the left at 4, on the right at 6 inches.

153. *Observation by Brenner. Ringing in the Ears after the Use of Quinine. Simple Galvanic Hyperæsthesia. Cure.*—A nun, aged 33. Had taken large doses of quinine for several weeks, on account of an obstinate tertian ague, and had thereby acquired an extremely troublesome, incessant ringing in the ears, which had remained unaltered for 3 months; some diminution of hearing on both sides. Otological examination gave an entirely negative result, and repeated air douches had no effect. Galvanic examination showed a moderate degree of simple hyperæsthesia and complete cessation of the tinnitus with AC and AD. A favourable prognosis was thus established, and treatment was commenced with AD and careful opening of the current. After the first sitting the ringing stopped for two hours; after the second it disappeared till evening; after the sixth it did not reach its former intensity in 24 hours and changed its tone; after the fifteenth the patient was entirely cured—the head clear, the spirits lighter, and the embarrassment of the hearing gone.

154. *Personal Observation. Impairment of Hearing and Tinnitus Aurium. Double-sided Hyperæsthesia of the Auditory Nerve. Paresis of the Right Abducens.*—A shoemaker, aged 59. Difficulty of hearing and ringing in the ears for 6 months, persisting day and night; much the same on both sides, like ringing of bells or boiling of water. Increasing dizziness for 4 weeks; head much confused and tense; diplopia for 3 weeks. Condition on January 7, 1870: Paresis of the right abducens. Otological condition (Prof. Moos): Chronic catarrh of the middle ear; on each side diffused opacity of the tympanic membrane with diminution of the light spot; peripheral wrinkling of the membrane. Eustachian tubes pervious. Conduction through the bones weak, better on the right side than on the left. Clock (which could be heard 30 feet off) heard at 8 inches on the right, 5 inches on the left; after catheterisation, at 12 inches right, 9 inches left. Galvanic examination gave on both sides the typical formula of simple hyperæsthesia. During AD complete disappearance of the tinnitus. The treatment (apart from that of the abducens paralysis) consisted in energetic employment of AD to each ear, with gradual cessation of the current. Ringing completely disappeared immediately after first sitting, head clear and light, dizziness gone; ringing less next day. After 10 sittings paresis of abducens much improved; tinnitus decidedly less, occurring only temporarily. After 19 sittings tinnitus very slight, only complaint as to dizziness. Tinnitus produced by action of K, overcome for a moment by KO,

and completely routed by AD. Gradual progress towards improvement. On March 31 (after 44 sittings) discharged in the following condition: Diplopia almost entirely disappeared. Tinnitus as good as entirely gone, only occurring temporarily on the left side; extent of hearing a little improved. Moderate degree of hyperæsthesia still on left side, no longer marked on right.

155. *Observation by Hagen. Tinnitus Aurium and Impairment of Hearing. Simple Hyperæsthesia of both Auditoria.*—A man, aged 42. Six years ago ringing in the ears and difficulty of hearing, from cold, on the left side, and 4 years ago also on the right. Since then gradually getting worse. Right ear: Tympanic membrane opaque; light spot absent; tick of clock, audible at 20 feet, heard at 9 inches. Left ear: Tympanic membrane streaked with greyish white radiations; light spot absent, &c. Tick heard at 11 inches. Tuning fork placed on the top of the head heard with equal loudness on both sides. Pharyngeal catarrh. Eustachian tubes pervious, air entering in thin streams on each side. Continued otological treatment raised the distance of hearing on the right to 1 foot, on the left to 1 foot 7 inches, but without diminution of the subjective auditory sensations. Galvanic examination gave the formula for simple hyperæsthesia on both sides. Treatment with AD caused the noises in both ears to disappear at once. After 5 sittings permanent diminution of the ringing; after 16, complete and permanent disappearance. Distance for hearing raised to 4 feet on the right side, 2 feet on the left. Opacity of tympanic membrane disappeared, light spot distinctly visible.

156. *Observation by Hagen. Tinnitus Aurium. Simple Hyperæsthesia of the Auditory Nerve.*—A woman, aged 59. Threefold subjective sensation in the right ear, singing, whistling, and hissing. Very hard of hearing on the right side; tympanic membrane intensely yellow, not translucent; no light spot; slight mucous rattling with the air douche. Catheterisation, air douche, and strychnine injections in vain. Galvanic examination shows simple hyperæsthesia. Hissing and whistling arrested by AD, but singing unaltered. After a few sittings (AD with gradual opening of the circuit) hissing and whistling permanently removed, singing unaltered, only two of the subjective sounds cured. Methodical use of the K entirely without effect.

157. *Observation by Hagen. Tinnitus Aurium and Impairment of Hearing on Both Sides. Simple Hyperæsthesia. Very Rapid Cure.*—A shoemaker, aged 34. Tinnitus and difficulty of hearing for 3 years on the right side, a year and a half on the left. Condition: Moderate tympanic opacity on the right side, light spot dull, long

arm of anvil not visible. On the left tympanic membrane an opaque greyish white in its posterior quadrant, light spot dull, manubrium much shortened. Tick not heard on either side; very loud voice heard at 1 foot. Conduction of sound through the bones louder on the right than on the left. Eustachian tubes pervious. No influence on hearing or tinnitus by catheterisation. Hyperæsthesia of some degree of severity found galvanically on both sides. Tinnitus in both ears removed at once by the action of AD and gradual opening of the circuit, so completely that a second treatment was not necessary; cure permanent after several weeks.

158. *Observation by Brenner. Long-standing Ringing in the Head and Ears, with Impairment of Hearing. Hyperæsthesia with a Paradoxical Formula.*—A physician, aged 50. Had suffered since childhood from great difficulty of hearing and troublesome subjective auditory sensations. Watch heard on the right side when laid against the ear, on the left not at all; conduction through the bones present; Eustachian tubes clear. Both membranes very opaque, &c. Patient distinguished a deeper sound of another character, besides the ringing in the ears, which he located in a spot in the occipital region; and he complained also of blows as of lightning at the moment of falling asleep, which consisted of detonations, followed by twitchings. Galvanism showed enormous hyperæsthesia of both auditory nerves, with paradoxical reaction in the ear not treated. Complete disappearance of the head sounds during AD, the ear sounds remaining unaffected. Repeated galvanic treatment for some months, with very good results. Steady diminution of the head ringing; less intensity in the lightning concussions on falling asleep, and finally disappearance of the same; increase in hearing, greater clearness of the head, improvement of spirits, only the ringing in the ears left.

159. *Observation by Hagen. Impairment of Hearing and Tinnitus Aurium. Hyperæsthesia with Reversal of the Normal Formula.*—A female factory hand, aged 17. Hard of hearing and suffering from subjective noises (roaring, singing, tolling, and ringing) for 3 months on both sides, left more than right. No wax on either side. Tympanic membrane opaque; no light spot. Eustachian tubes clear; conduction through the bones equal on both sides. Repeater watch heard at 4 inches on the right, 1 inch on the left. No influence on the fourfold noise after several weeks of otological treatment. Galvanic examination gave the following formula for both ears, the right requiring a stronger current that the left:—

KC	—
KD	—
KOC′	feeble hissing.
ACC′	loud hissing.
ADC	∞ hissing persistent.
AO	—

KD immediately improved the subjective sounds. The left ear then treated with KD and gradual cessation. Result: The four subjective sounds of the left ear disappeared, and at the same time complete quietness in the right ear, which was not treated. Right ear remained free permanently; in the left the roaring first disappeared; the singing, tolling, and ringing returned soon after the first sitting, and were again immediately removed by the KD treatment, the singing permanently. After the 8th sitting the singing temporarily returned, to be permanently cured after the 17th sitting. Hearing somewhat improved; KO reaction disappeared from the galvanic formula, but the normal not yet reached. The cure persisted.

160. *Observation by Moos. Impairment of Hearing with Tinnitus Aurium after Cerebro-Spinal Meningitis.*—A peasant lad, aged 21. Suffered from cerebro-spinal meningitis in 1866, during which he was perfectly deaf; subsequent improvement in the left ear, none in the right; loud subjective sounds on both sides. Summer 1867: Completely deaf on right side; watch, carrying for 6 feet, heard at 3 feet on the left side, talking at 2 paces; complete deafness for deep notes. Accurate examination showed integrity in the mechanism of the auditory apparatus. The greatest variety of otological treatment without any result. Formula of simple hyperæsthesia on the left ear; subjective noise deadened by AD; after the first sitting talking heard at 6 paces, the watch at 6 feet. In the right ear loud hissing with KC, but no improvement on further treatment, while on the left side after 22 sittings talking could be heard at 18 paces and the subjective noises were much moderated.

From these cases it may be gathered which method of treatment will succeed each time, and how it may be deduced from the results of the examination. It must be held fast as a general rule that those stimuli which deaden or silence the subjective noise must be brought to bear with the greatest possible intensity and duration, whilst, on the other hand, those which increase the buzzing must have their stimulating action diminished as much as possible, or even abolished, by cautious opening and closing of the current. The restoration of the normal formula frequently takes place at the same time by the encouragement of the weakened or absent stimuli or by the evasion of those which act too energetically.

For individual practical cases the procedure is simply as follows:—

In buzzing of the ears, combined with simple hyperæsthesia, which is diminished by AD (the most frequent case), begin with A at its full strength, and, after AD has acted sufficiently, diminish the current very gradually and in such small stages (by means of the rheostat or by lessening the number of cells) that all opening stimulation will be avoided, so that there shall be no sensation of opening and also no buzzing during this gradual cessation. You must often do this very slowly and carefully, sometimes going back to a greater strength of current, and lengthening the duration of the sitting, before it is possible to get a cessation entirely free from irritation; and for this many expedients are necessary. If you wish to increase the action of AD by a previous reversal of the current, begin with K at a minimum strength, let this gradually increase, then rapidly change to AD, and then proceed as has just been described.

But if the hyperæsthesia is so great that the 'paradoxical reaction,' the alternating combined ringing of the other ear, is present, you may lose in the one ear what you have just gained in the other; and for such a case the proper method is to furnish both ears with one divided electrode and then carry out the treatment in the way just described. This may be very quickly successful, and it may also be employed in double-sided simple hyperæsthesia of a moderate degree.

But if tinnitus aurium is combined with hyperæsthesia with reversal of the normal formula you will often find that the tinnitus is lessened by the action of KD, whilst it is increased by AC and AD. In that case you must proceed in an exactly opposite manner, by forcing and prolonging the action of KC and KD as much as possible, preventing KO by gradual opening and AC by cautious closing of the circuit; otherwise the procedure is exactly the same as in simple hyperæsthesia.

The circumstances become more difficult, however, if other anomalies of the normal formula are present, with or without hyperæsthesia, e.g. if all kinds of irritation are responded to by a sensation of sound, and the like. It must then be often left to the tact and good fortune of the practitioner to decide which procedure will be successful in the individual case. Systematic and rational experiments will be the best. As guiding data you may hold fast to the following: First endeavour to find out what will deaden the buzzing, whether AD or KD, and direct the treatment accordingly. It may also be of importance whether the pathological irritations have become stronger than the normal, i.e. whether a reversal of the formula is near or not. In the first case the same treatment as in reversal of the formula must be preferred; in the second the treatment will be the same as in simple hyperæsthesia. Finally, you may try to bring the auditory nerves gradually back to the normal formula by regular galvanic treatment; to overcome the pathological irritation and to favour the normal, and so, perhaps, to obtain a favourable reaction on the nervous affection.

But you must not, under any circumstances, allow yourselves to be frightened away from one or other method, or even from the continuance of your therapeutical experiments, by theoretical considerations, until you have exhausted all available processes. All possible attempts at cure are permissible; electrotonus is not despotic even on this its most undisputed domain, and the possibility is not so far-fetched that results may gradually be attained, by means of the cautious katalytic action of the current, with changes of polarity, which will be denied to its direct, modifying action. This may, perhaps, enable us to understand the remarkable assertion of Benedikt, that reversals of the current are the best treatment for deafness as well as for tinnitus.

These rules apply also to all the rarer anomalies of reaction, which have not yet been described, to the very irregular formulæ, with tinnitus, and also to the cases in which galvanic examination gives no definite result. In such cases, if the other otological methods have been tried and have been exhausted, you may certainly, on the grounds of experience, try even a vague and apparently purposeless electrical treatment, and carry it out for some time consecutively and systematically.

I have repeatedly seen improvement in this way from perseverance and patience. For such patients I would even consider a trial of the faradic current to be justifiable, as some observers (Schivardi and others) have reported remarkable results from its use. Its therapeutical action upon the auditory nerve itself, as well as upon the brain, vasomotor nerves, &c., is by no means to be excluded.

To say a word as to the technique of this method of treatment, it requires in most cases an unusually high degree of exactitude and neatness in carrying it out, trustworthy apparatus, with skill and judgment in its use, an exact knowledge of the facts belonging to the subject, and a clear idea of what ought to be accomplished. As all these conditions are very seldom combined, this may be partly the reason why many observers, and especially certain aurists who were very little or not at all conversant with electrotherapeutical measures, had such very unsatisfactory results. You will find it best to use the 'external arrangement of experiment' (vide p. 154), electrode B being in the opposite hand or, less advantageously, at the nape of the neck. Firm fixation of the electrodes is necessary; the reversers of the current and all parts of the apparatus must be so arranged that unintentional interruptions and shocks may be avoided as much as possible, and very special care must be employed in making and breaking the current. This last will often give you a great deal of trouble, for in very great hyperæsthesia a very small lessening of the strength of the current may induce sensations or buzzing. Weakening of the current by diminishing the number of cells, combined with a diminution of the rheostatic resistance (in the secondary coil), lingering on the lower degrees of the current before making it weaker still, sometimes even a temporary increase in the strength, and, finally, removing the ear electrode by letting it glide over the surface of the hair, are the means by which you may generally succeed. Very sensitive individuals, in whom the secondary symptoms are strongly developed, must often be accustomed to very weak currents before passing on to the stronger and only really effectual currents.

The sittings must often be tolerably long, if success is to be certain—from 5 to 15 or 20 minutes -and their repetition must be decided each time according to circumstances.

The *results* of the electrical treatment of tinnitus aurium are very varied—sometimes brilliant and rapid, sometimes only coming on gradually, sometimes failing altogether. It cannot yet be decided in what proportion the successes stand to the failures; the cases are, indeed, too dissimilar. In the most favourable forms (simple hyperæsthesia with certain diminution of the tinnitus by AD) the course of the case generally is that the buzzing ceases after the sitting for a quarter or half an hour, or for several hours, sometimes even till the next day. It very rarely completely disappears after one sitting, although even that sometimes happens (Obs. 157). As a rule it returns, after the time mentioned, with gradually increasing strength, to be again driven away at the next sitting, and this time for somewhat longer. Cure is thus gradually induced. The more rapidly the buzzing returns after the first sitting, the nearer it comes to its former intensity, and the more exactly it presents the same characters as before, the more slowly will cure result, and *vice versa*. But, according to the experience which we have got, all those forms of tinnitus which can be entirely silenced by AD appear to be curable. In the less favourable cases it may be a long time before good results are attained, and you will often have to try various methods of treatment and many modifications of the instruments used before you succeed. This, however, only makes such cases the more interesting, although the result may not seem so brilliant. You must not be afraid to make a thorough trial of the electric current even though opposed by the patient, if all other remedies have been exhausted. It has been my repeated experience that buzzing in the ear which was at first not at all amenable to the current has been improved and even removed by galvanic treatment after a pause of six months or a year.

From the observations already communicated, it will be seen that *nervous impairment of hearing* is very often capable of improvement by means of the galvanic current, and that the same manipulations which cause the disappearance of the buzzing often induce a very marked improvement in the hearing (vide Obs. 152, 155, 160). But there are other cases of deafness in which tinnitus is present, but in which a nervous origin is at least highly probable, partly from the absence of any visible disease of the ear itself, partly from the presence of anomalous galvanic reaction formula, and partly from all kinds of accompanying nervous disturbances. I will adduce a few examples of this.

161. *Observation by Brenner. Impairment of Hearing without Perceptible Anatomical Changes. Anomalous Galvanic Reaction*.—A student, aged 23. Difficulty of hearing for two years. Otological investigation showed no anatomical change. Watch tick heard on the right at 5 inches, on the left at 3. Talking heard at 3 feet, whispering only when quite close. Galvanic reaction formula :—

$$\begin{array}{ll} \text{KCK} & \\ \text{KDk} > & \\ \left.\begin{array}{l}\text{KOk}\\ \text{ACK}\\ \text{ADk} >\end{array}\right\} & \text{ringing sensation of a different timbre.} \\ \text{AOk} & \end{array}$$

The treatment had for its object to avoid the AC reaction by gradual closure, to strengthen the AO reaction by long continuance of the current, to increase the KC reaction by changing from A to K, and to avoid the KO reaction by gradual opening. After 2 months watch heard on the right at 12, on the left at 7 inches. Marked improvement for speaking, moderate speaking being heard at 7 feet and whispering at 2 feet. The pathological reactions required stronger currents to induce them, and the normal reactions had become more intense.

162. *Observation by Brenner. Difficulty of Hearing with Anatomical Change. Torpor of the Auditory Nerve. Decided Improvement.*—A widow, aged 50. Increasing difficulty of hearing for 17 years, with severe buzzing in the ears and consequent depression of spirits. Watch heard when close to the ear, conducted through the bones of the head. Tympanic membrane slightly opaque ; light spot normal ; malleus very prominent ; Eustachian tubes clear, &c. Long and persevering otological treatment removed the buzzing, and improved the hearing so much in the right ear that the watch could be heard at 46 inches on that side, but only at 2½ on the left. Galvanically the right auditory nerve showed an almost normal formula, but the left all the signs of torpid reaction (p. 241). The left ear was treated galvanically, and the irritability of the nerve sought to be raised by reversals from A to K. Result :—

1st sitting:	Hearing at	2½	in.
2nd ,,	,,	3½	,,
6th ,,	,,	6½	,,
9th ,,	,,	11	,,
10th ,,	,,	15	,,

The signs of lowered irritability diminished; the KD and AO reactions appeared. Treatment discontinued.

In these and similar cases the galvanic current deserves a trial. Treatment must first be directed to finding out the formula and its anomalies, and it consists in suitable endeavours to remove these anomalies and to restore the formula to its normal condition, as also to lessen the torpor of the auditory nerve by repeated stimulation and to increase its irritability by the modifying action of the current. If no anomalies of the reaction formula are present the treatment must be commenced and carried through entirely according to general rules.

The attempts to improve congenital deafness, and thereby *deaf mutism*, by electrical means have as yet led to very unsatisfactory results, but a few such observations occur. It does not appear to me necessary to say anything special about the methods to be employed.

The so called *Menière's disease*, on the contrary, deserves a short notice here, as it is also to be referred to a disease of the nervous auditory apparatus. The sudden deafness, the frequent tinnitus, combined with severe dizziness and vomiting, the absence of any change in the external and middle ear, as well as the results of investigation in testing the auditory nerve itself, sufficiently prove this. It is not yet certain whether it depends upon an extravasation of blood into the labyrinth or upon inflammation or the like.

The galvanic current may, however, be tried for this not very hopeful disease, whether it is done in the manner determined by the reaction formula which may be present, or according to the rules which are suitable for the treatment of intracranial anatomical processes generally.

From the foregoing, gentlemen, it will have become evident to you that much, not little, may be accomplished in nervous auditory affections by means of the electric current. It must strike us as all the more strange to see that many, even prominent aurists judge the diagnostic and therapeutic significance of this valuable remedy with contempt, and take pains to ignore it, hardly granting it a passing mention in their class books and handbooks. These doctors may settle it with their own consciences when they withhold from their sorely tried patients the use of a remedy whose value has been proved beyond a doubt by numerous authentic observations; but science will pass over the disapproving vote of such writers, founded on ignorance of the subject, and will not allow itself to be deprived by them of its joy in the well-earned and interesting facts and practical results.

NEUROSES OF THE GUSTATORY NERVES

are very rarely the subject of special electrical treatment. The only disturbance of them which now and then comes to be considered is paralysis of taste, *ageusis*. This is hardly ever found isolated, by itself, but very often as a symptom of various nervous diseases, as in lesions of the trigeminus at the base of the skull, lesions of the chorda tympani in the middle ear, rheumatic and traumatic paralysis of the facial, peripheral lesions of the lingual, or diseases of the glosso-pharyngeal, also in certain cerebral diseases, in hemianæsthesia with implication of the other organs of sense, and particularly often in hysterical hemianæsthesia.

You know already that all or most of these lesions may also be treated electrically; first of all, then, the treatment of the fundamental lesion is to be entered upon, according to the methods known to you, which may be very different for the various cases (galvanisation transversely and longitudinally through the skull, treatment of the facial and trigeminus paralysis, &c.; vide previous lectures).

Upon this the disturbance of taste will generally disappear quickly and easily, as in rheumatic facial paralysis, provided, of course, that it depends upon a lesion which is curable in itself. As a rule you will not find it necessary to proceed directly against the ageusis; but sometimes it persists longer than the fundamental affection, or it may even remain permanent.

If you consider direct interference to be desirable, it seems most suitable to stimulate the gustatory nerves directly from the tongue and the buccal cavity, preferably with the galvanic current. You will stroke thoroughly the whole of the mucous membrane concerned with a small sponge electrode (pharyngeal electrode, p. 487), or with Neumann's pair of electrodes, consisting of knobbed sounds, for a few minutes, and with a strength of current of whose power to excite distinct sensations of taste you have persuaded yourself, either on the healthy half of the tongue of the patient or on yourself, or which you have determined by the galvanometer.

NEUROSES OF THE OLFACTORY NERVES

are still more rare and unimportant than those of the nerves of taste, although they often cause a much more considerable derangement of perception.

Here also diminution of the sense of smell, *anosmia*, has alone been the subject of electrotherapeutic experiments. It occurs not very rarely by itself alone (from diseases of the nose itself, lesion of the olfactory nerves by injuries of the skull, degeneration from senile processes, &c.), but frequently also combined with other nervous derangements, which are dependent on the fundamental affection (cerebral tumours, gunshot wounds of the orbit, meningitis, cerebral hæmorrhages, hysteria, &c.) With regard to the localisation of the therapeutical influences it may specially be mentioned that anosmia on the left side is often seen in connection with right hemiplegia and aphasia; that anosmia with hemianæsthesia and implication of the other nerves of special sense points to the seat of lesion being in the internal capsule; but that the seat of cortical anosmia has still to be more accurately defined (probably the temporal lobes).

There are some cases in literature of successful electrical treatment of anosmia. Duchenne has seen good results from faradisation of the nasal mucous membrane, chiefly in hysterical patients. Bärwinkel treated three cases of anosmia which had lasted for from 1 to 10 years (probably caused by catarrh), curing 2 cases and improving the third after 6 sittings. His method consisted in galvanisation with a weak current from the nape of the neck to the nasal mucous membrane, the catheter-shaped electrode being moved backwards and forwards, especially at the posterior part; this caused characteristic subjective sensations of smell and copious secretion. Fieber also saw some benefit from the employment of the galvanic current, with olive-shaped electrodes, in both nares. Neftel found the sense of smell, which had been lost for 20 years, return during the galvanic treatment of a case of tinnitus aurium. Beard also observed improvement in a case from external and internal galvanic treatment of the nose; and Ferrier cured, in a few weeks, a traumatic anosmia which had lasted for years, by means of the galvanic current (transversely through the zygomatic fossæ or from the root of the nose to one of the fossæ).

There is, therefore, no doubt that many cases of anosmia may be cured by electricity. The methods to be employed are self-evident. First the fundamental affection causing it must be attacked; then a galvanic treatment of the olfactory nerves themselves must be tried, with transverse passage of the current through the anterior part of the temples or longitudinally from the root of the nose to the nape, with reversals of the current. To this may be added direct treatment proceeding from the nasal cavity itself, by means of a thin, catheter-shaped, knobbed electrode, isolated as far as the point, which is to be passed into the nose and moved backwards and forwards over as much of the mucous membrane as possible, especially towards the upper part; this may be done with the faradic current as well as with the galvanic (kathode). The occurrence of great pain will generally give sufficient warning of the current being too strong.

XI. *DISEASES OF THE ORGANS OF MOTION, OF THE GLANDS, OF THE THORACIC VISCERA, AND OF THE DIGESTIVE APPARATUS.*

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LECTURE XXXV.

Diseases of the Organs of Motion—Muscular Rheumatism—Its Varieties and Character—Different Forms of Treatment—Results—Articular Affections—Introduction—Acute Articular Inflammations—Traumatic and Other Forms—Polyarthritis Rheumatica—Chronic Inflammation of the Joints—1, Chronic Monoarticular Rheumatism—2, Chronic Polyarticular Rheumatism—3, Arthritis Deformans—4, Stiffness and Ankylosis of the Joints—Diseases of the Glandular Organs—Lymphatic Glandular Tumours—Struma—Splenic Tumours—Diseases of the Thoracic Organs—Nervous Asthma—Nervous Palpitation—Cardiac Debility and Irregularity.

In this section I have to discuss a series of diseases in which also the electric current occasionally shows very remarkable curative action. These are numerous organic disorders, partly nervous, partly not nervous in character, some of them of great practical importance and of high scientific and therapeutic interest; some of less significance, but still worthy of mention here, were it only to give you as complete a picture as possible of the curative sphere of the electric current in internal therapeutics. In doing so we shall, indeed, come sometimes upon the limits of its action.

I begin with

DISEASES OF THE ORGANS OF MOTION.

The active organs of motion, the muscles, have already occupied us so long that there is not much more left to say of them here. In particular I have already discussed at length the different varieties of atrophy and degeneration and also hypertrophy of the muscles (vide Lecture XXII., p. 437, and Lecture XXV., p. 504). We have here only to mention a very frequent and painful affection, which is generally known under the name of muscular rheumatism, and in which electrical treatment has usually very beneficial results. Muscular rheumatism occurs, as everyone knows, in a great variety of forms and in all possible muscles of the body, and is named accordingly in different ways; it is best to include all under the general name of myalgia. We can then differentiate rheumatism of the lumbar muscles as lumbago, of the cervical muscles as torticollis or caput obstipum, of the thoracic muscles as myalgia pectoralis or pleurodynia, and so on.

All these varieties occur frequently, are generally referred by patients to a chill or to a sudden strain or jerk of the muscles, and are in all cases very painful and often extremely obstinate, defying treatment sometimes for months and even years.

We are still quite in the dark as to the true nature of these affections. It is certainly only in the rarest cases that serious lesions can be present, and the famous 'rheumatic callus' must be only an anatomical curiosity, having, doubtless, very little to do with what we call myalgia rheumatica. We assume that in some cases the lesion consists in slight and very temporary disturbances of circulation, in hyperæmia, in fugitive inflammations with serous and other exudations; and in another class of cases in circumscribed rupture of a few muscular fasciculi with its consequences, or sometimes in neuritic or neuralgic affections of sensory nerve twigs in the muscles, muscular sheaths, or fasciæ. Lastly, in many cases there is a direct transition to tonic cramp of the muscles, which might equally well be called rheumatic contraction. In this uncertainty with regard to our pathological views, it is of course impracticable to commit ourselves to theoretical discussions as to the proper treatment. This will come of itself in discussing the different affections, and I shall, therefore, proceed at once to sketch out the customary and effective forms of treatment, of which we may employ three.

The first is the application of the faradic brush to the skin over the painful muscles, with a strong current, for a few minutes, until intense redness is produced, when the pains often disappear as if blown away. This can be repeated several times a day if necessary.

The second method is the powerful faradisation of the affected muscles themselves, recommended by Runge and Gubler, the current being strong enough to induce very severe and exhausting contractions. For application to the dorsal muscles larger electrodes ('medium-sized') must be used, both being placed on the muscle, and the current should be increased and diminished several times in one sitting, which may last 5 or 10 minutes. This proceeding is disagreeable, because the contraction of the affected muscles is in itself very painful, but the pain usually diminishes after a few such movements, the subsequent contractions are more bearable, and by the end of the sitting there is generally a marked improvement.

The third method, galvanic treatment, is much less severe and is equally efficacious, in many cases even more so. It consists in the application of the anode over the specially painful spot, whilst the kathode is placed either directly opposite, on some indifferent point, or on several points consecutively in a ring round the anode (Remak's 'circular currents'). For this purpose a stabile current of considerable strength (40° to 55° N defl. or 20 to 40 ma.) must be employed for some minutes, and at the end some interruptions and reversals of the current should be made, to induce powerful contractions of the muscle. Relief usually follows at once, and the proceeding may be repeated 2 or 3 times (duration of the entire sitting 5 to 15 minutes) until the pain has quite disappeared.

Poore recommends the combination of some kind of gymnastics (energetic active contractions) with this galvanic treatment; and Runge, indeed, recommends this alone as sufficient in many cases; but it would not be very agreeable to the patient.

The results of all these methods are usually extremely brilliant, and the cure of muscular rheumatism certainly belongs to the most hopeful province of electrotherapeutics. Considerable relief, often complete disappearance of the pain and stiffness, is experienced immediately after the treatment, not only in recent cases, but also, as I have found, in very obstinate cases of many months' standing. Indeed, I have seen immediate relief from the use of the galvanic current even in cases of acute febrile myalgia, but from 2 to 10 or even more applications are generally necessary in order to bring about this result.

Frequent and manifold are the attempts which have been made to cure joint affections by means of electricity. Froriep battled successfully against the various forms of articular rheumatism with his rotation apparatus, and Cahen later apparently cured an arthritis deformans by prolonged treatment with the induced current. R. Remak then made his first successful experiments on the katalytic action of the galvanic current in articular rheumatism, in acute, subacute, and chronic, traumatic and rheumatic articular inflammation, and thereby vindicated for the current a very high efficiency. Weisflog, on the other hand, has brought the antiphlogistic action of the faradic current in inflammation of the joints into the foreground, and in recent times series of favourable results from the application of the faradic current even in typical acute articular rheumatism have been published. Altogether, however, there have been only isolated observations and unsystematic accounts; there has not yet been anything like a regular or general recognition of the beneficial effect of the electric current in joint affections.

We shall consider here principally the various forms of inflammation of the joints, and it seems convenient to discuss the acute and chronic varieties separately.

ACUTE ARTICULAR INFLAMMATION.

Whilst some, like Joffroy in recent times, decry altogether the employment of electricity in acute inflammation of the joints, and others, like Weisflog, declare it to be impracticable and even hurtful, at least in all rheumatic inflammations, both the galvanic and faradic currents are recommended by others as applicable, and even in a very great degree useful.

The usefulness of electricity in acute traumatic inflammations, dislocation and its sequences, is certainly indubitable; Remak has obtained favourable results in such cases with galvanic, and Weisflog with faradic currents. The swelling, heat, and pain in the joints generally diminish rapidly after the sitting, the mobility increases, and a regular continuation of the treatment soon effects a cure. This treatment will be considerably assisted by skilful massage.

Remak has obtained very good results in spontaneous, rheumatic, and symptomatic inflammations, and Weisflog recognises them as subjects for faradic treatment, so that further electrotherapeutic experiments are much to be desired in all these forms of disease.

The treatment employed by Remak, and the one which is most to be recommended, consists in the passage of a rather strong, stabile, galvanic current through the joint, with alternation of the poles, but with a preponderating action of the anode, especially so long as the pain is great. This should be followed at the end of the sitting by some interruptions of the current, and by labile currents through the neighbouring muscles and along the course of the nearest blood vessels and lymphatics, whereby the circulation is promoted in all the tissues. The sitting should last from 10 to 20 minutes.

The method of faradic treatment employed and chiefly recommended by Weisflog consists in passing a strong faradic current through the joint several times a day for periods varying from $\frac{1}{4}$ to 1 hour, with large, moist electrodes, or by means of the local electric bath. Weisflog lets the current be applied in this way, by the patient himself, between 6 and 10 times in the 24 hours, day and night; he reports very good results.

It is different with the real acute articular rheumatism, polyarthritis rheumatica acuta. In it Weisflog condemns all attempts with the faradic current as hurtful. Remak has had too little experience of his own, but is inclined to ascribe a decidedly good effect to the galvanic current in acute febrile rheumatism, both on the local manifestations and on the fever and general dyscrasia, in so far as they proceed from and are kept up by the local affection; and he has been specially fortunate in treating the subsequent local lesions, pain, stiffness, muscular weakness, &c.

Recently, however, Drosdoff has made surprising communications from Botkin's clinic on the relations of acute rheumatism to the galvanic current, which must lead to further investigations. Drosdoff found, in the first place, the sensitiveness to the faradic current (with moist electrodes) very much lowered in the affected joints;[1] but, besides that, he found that faradisation for 5 to 10 minutes with a powerful current reduced the increased temperature of the joint to normal, moderated the pain for some hours, and by daily repetition brought about a short and uncomplicated course of the whole illness. These results have been fully confirmed in all essential points by Beetz in von Ziemssen's clinic; he also found a remarkable diminution of the pain, greater mobility of the joint, and shortening of the whole illness from a faradisation of 5 or 10 minutes. He regards the faradic current as a valuable and trustworthy palliative, which may be advantageously combined with other remedies. Abramovski observed the same results—diminution of the pain for several hours, permanent improvement after a few sittings—from the employment of the faradic brush over the joints for 10 or 15 minutes daily, but could not find any analgesia, at least of the skin, to result from it.

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[1] Weisflog found the same in other forms of articular inflammation.

As we have found a brilliant and seldom failing remedy for acute articular rheumatism in the salicylic acid treatment, you will have little desire or inducement to try the tedious and troublesome methods of galvanism and faradisation. But as there are always isolated cases, in which the treatment with salicylic and benzoic acids fails, in which even the subcutaneous injection of carbolic acid into the neighbourhood of the joint is not effectual in subduing the pain, you will turn now and then to the electric current in acute rheumatism, and will find it at least a tolerably sure and easily applied palliative, in combination with internal treatment. The faradic treatment, either with moist electrodes or with the brush, should, I consider, be first tried, each joint being treated once or twice a day for 5 or 10 minutes; and afterwards the galvanic current may be employed, either alone or alternately with the faradic.

In any case it would be very desirable, both on theoretical grounds and for the better knowledge of the katalytic actions of the electric current, if it could be tested in a more extensive and systematic manner in these acute articular affections.

CHRONIC ARTICULAR INFLAMMATIONS.

Among joint affections these are indeed the special sphere for electricity; because the ordinary treatment fails much oftener here, the disease drags on for years, and there is, therefore, abundant room for an attempt with the electric current. Here also it is those forms in which the tissues around the joint are principally affected, and in which deeper degenerative metamorphosis of cartilage and bone is absent, which are suitable for this treatment. It will be advisable to distinguish between the different varieties.

1. *Monoarticular chronic rheumatism* is a tolerably frequent affection, which may be localised in different joints, but which occurs most frequently in the shoulder and the knee, then in the elbow and the ankle, &c. It is sometimes associated with copious exudation of fluid (hydrarthros), but can often be recognised only by thickening of the tissues, stiffness and great pain on movement, roughness and creaking in the joint, and the like; very commonly combined with considerable secondary atrophy of the muscles, most frequent and marked in the deltoid and quadriceps femoris. It occurs in consequence of injury, or from chill, gonorrhœa, &c., also spontaneously and from scrofulous causes (tumor albus); and it is generally a very obstinate affection, treated in vain by the usual surgical means (firm bandaging, iodine, massage, baths, &c.)

This joint affection is certainly one of the most favourable varieties for electric treatment; and the reports of former authors (Froriep, Meyer, R. Remak, Weisflog, and others) on the results of galvanism and faradisation have been confirmed by E. Remak and by myself.

The most suitable methods of treatment are the following:—

Galvanic: as what is wanted here is the katalytic action, stabile currents, sent in all directions through the middle of the joint, are in the first place to be recommended, and frequent reversal of the current will increase the effect. In more recent cases weaker currents and a predominance of the anode are to be preferred; in older cases stronger currents and the energetic use of the kathode. Besides this, a closing application of a labile current to the neighbouring muscles, vessels, and lymphatics seems to be very useful. The sitting should last from 5 to 20 minutes.

Seeligmüller has recently recommended a method with which he has achieved beneficial and rapid results even in severe and obstinate cases. It consists in the application of the galvanic (K) brush to the skin in the line of the joint, and passing it along in such a way that it shall rest from 1 to 10 seconds on each spot, so as to cause a small eschar. The current must be powerful, and the method is, therefore, very painful; but its results seem to be most satisfactory, as is proved by the communications of Böttger.

The faradic current can be applied by means of moist electrodes or suitably arranged local baths; the current should be tolerably strong, and the sittings should last from 10 to 15 minutes. According to Weisflog, there ought to be several sittings in the day, each lasting from ½ to 1 hour.

The faradic brush may also be employed, especially where an energetic determination to the skin, in the neighbourhood of the joint, is desired, or where great pain in the joint indicates its use.

For the secondary muscular atrophy either labile galvanic currents, KC and changes of polarity, regular faradisation of the muscles, or, finally, the weak continuous galvanic current so strongly recommended by Le Fort and Valtat (vide supra and Lecture XXV., p. 506) may be employed.

2. *Polyarticular chronic rheumatism* is often nothing more than a reduplicated form of the affection just considered, or it may develope as a sequela of a specific acute articular rheumatism. It is, under all circumstances, a troublesome and obstinate affection, in which, however, electricity sometimes proves useful, as the observations of Erdmann and others show.

The treatment is carried out in the very same way as in the former variety, only that here the application must be made to each joint separately. Mixed treatment, as employed by Erdmann in his case (faradic brush, faradisation, and galvanisation of the joints and muscles), will perhaps attain the desired end more quickly.

3. *Arthritis deformans*, or *rheumatismus nodosus*, is one of the worst of the forms we have here to consider, and it usually resists the electric current as obstinately as it does all other treatment. Opinions are divided as to its nature; there are probably several forms, one occurring chiefly in the larger joints and in the spine, belonging to later life (malum senile), another affecting principally the small joints of the fingers and toes, and beginning in middle life, from rheumatic

causes (arthritis pauperum;) and, lastly, probably another form, trophoneurotic in origin, which must, therefore, be regarded as a neurosis. The results which Remak, Meyer, and others have seen from the galvanic treatment of the sympathetic and of the spinal cord in this affection serve, as much as anything else, to support the view of its nervous origin.

The disease always lasts for years, and generally for a whole lifetime, runs its course with the formation of nodules and deformities of the joints, acute pain, secondary muscular atrophy, and general feebleness, and changes the individuals affected to incapable and extremely helpless creatures.

Cahen's case, treated faradically and cured in six months, belongs to this category; Remak reports good results from galvanic treatment (especially in the form of diplegic excitation); Moritz Meyer has cured several cases by galvanisation of the sympathetic; and Althaus saw satisfactory results from the galvanic treatment of the back and of the joints themselves. The results related by Chéron, who claims to have treated successfully all possible incurable diseases, are so brilliant that they seem scarcely credible; he acts, locally only, upon the joints, muscles, and nerves with powerful stabile galvanic currents for 10 or 20 minutes at a time. Joffroy has seen only moderate results, and Weisflog looks on faradisation not as a cure for this form, but at the most as a temporary palliative. I have myself treated a whole series of cases, almost always without any result, although here and there with arrest and improvement in the disease, with subjective relief to the patient and a favourable effect on the general conditions. The malum senile is, of course, the least favourable; you will here hardly venture to expect more than a temporary improvement.

Besides the local treatment of the joints, which is to be carried out in the same way as in the other forms of chronic rheumatism, I would recommend before everything the regular galvanisation of the cervical sympathetic and of the corresponding nervous plexus, and perhaps still more the treatment of the spinal cord itself, especially the cervical enlargement if the upper extremities are specially affected, and the lumbar enlargement for the lower extremities.

The removal of the general weakness and of the muscular atrophy, and the improvement of the innervation of the skin, as well as of the frequent anomalies of sweating, &c., will be best effected by a suitable labile galvanisation of the plexus, of the principal nerve trunks, and of the muscles of the extremities. Experiments with general faradisation and with the electric bath (Lehr) are also justifiable, as well as Seeligmüller's combined treatment, which has just been described.

It is obvious, from the tendency of the affection to increase, that the electrical treatment becomes very extensive and tedious; the duration of the sittings may be from 10 to 15 minutes and more; and the time occupied by the whole course of treatment must also be very considerable, if good results are to be obtained. Treatment for months at a time, repeated for years, is generally necessary; patience, therefore, must not be lost.

4. *Ankyloses, stiffness of the joints, periarthritic swellings*, and the like, as they are observed after injuries, gunshot wounds, too prolonged surgical bandaging, &c., are also objects of profitable electrical treatment. Moritz Meyer saw such disappear under the action of the galvanic current, especially with the anode; and Chéron, on the other hand, has found the stabile and labile action of the kathode useful in similar cases. It appears to be immaterial which pole is employed; and probably it is best to use both consecutively, with changes of polarity, in order to obtain the intensest possible katalytic action. In making trials in this direction, therefore, employ stabile and labile reversed currents on the affected parts. Massage will here prove a useful adjunct to electrotherapeutics.

I have already spoken of the treatment of articular neuroses in connection with neuralgia (vide Lecture XXVII., p. 536).

DISEASES OF THE GLANDULAR ORGANS.

Remak, in his 'Galvanotherapie' (p. 282), while engaged in describing the katalytic treatment of a case of remarkable muscular swelling of the forearm, mentions that he had succeeded, in the same patient, in removing a number of swollen and painful lymphatic glands in the neck, and in reducing the size of a long-standing and painful goitre. Since then, glandular tumours and goitres have repeatedly been treated electrically by other observers, to some extent with brilliant results.

Seeger, Chvostek, Onimus and Legros, and Picot have employed, like Remak, the galvanic current for the removal of lymphatic glandular tumours, and have found the best treatment to consist in the stabile and labile passage of a current through them and the neighbouring lymphatic vessels. According to Onimus and Legros it seems as if the predominant action of the anode were most advisable, but here, as in all cases where katalytic effects are desired, it is certainly best to change the direction of the current, and to let both poles act successively, even if in one case the anode, in another the kathode be allowed the advantage of a longer period of action. The cataphoric injection of iodine (according to the improved method of Munk; vide Lecture VII., p. 127) may also be employed in conveniently situated glands.

But the faradic current has also been employed with success in some cases to remove glandular tumours. Duchenne has cured cervical glandular swellings by means of the faradic current; Boulu has reduced parotid tumours with the rotation apparatus; and Meyer tells of one case of a cervical glandular tumour, the size of a hen's egg, which he reduced to that of a plum kernel in 60 sittings with the faradic current. There is, finally, the very remarkable observation of a tumour of stony hardness, larger than a man's head, situated between the head and the shoulder-blade, which was permanently reduced to a minimum by means of the faradic current (certainly only after 273 sittings of from 1 to 1½ hour each).

Meyer has recently indicated a method by means of which, in certain cases, this tedious treatment may be shortened. He has found that frequent interruptions of a very strong faradic current, passed through the tumour for 5 to 10 minutes, causes an actual division of the mass into several small glands, and thereby considerably facilitates its reduction and absorption. This method, which has only as yet been tried in two cases, deserves further testing.

Chvostek has published a large series of observations on the galvanic treatment of goitre, and has reported a wonderfully rapid cure in some cases, but has frequently brought about only a partial diminution, and in a few instances no result at all. His method consists in the passing of a stabile current for 5 or 10 minutes daily, the length of duration of the treatment being variable.

Here must also be recorded the different attempts that have been made to diminish and cure the various forms of enlargement of the spleen by means of electric currents. Chvostek, incited by a short notice of Fieber's, seems to have first made this experiment in a systematic manner and with accurate observation, and he has come to the conclusion that a considerable diminution of the spleen, recognisable by percussion, can be brought about by the electric current. This is dependent on reflex action, the skin being powerfully faradised by means of two brushes for about 3 minutes at a time. In this way first a temporary and after regular treatment a permanent diminution of the tumour is brought about, especially in those tumours which are found in intermittent fever and the malarial cachexia. Chvostek, who reports a great number of striking results, even in cases where quinine in large doses has proved useless, explains this decrease in size as arising from the reflex contraction of the unstriated muscular fibres in the splenic tissue itself, and still more from the contraction of the blood vessels contained in it.

Botkin is also persuaded of the action of the faradic current in splenic tumours of all kinds, but he acts directly upon the enlarged spleen by means of moist electrodes. He saw results even in the spleen of leukæmia; and Berger (according to Mosler) has also seen a leukæmic spleen considerably reduced by faradisation of the skin in the neighbourhood, but, on the other hand, neither Elias, Mosler, nor von Ziemssen has experienced this. Popow has seen a case of the beneficial effect of faradisation on malarial tumours, and Skorczewsky has found, almost invariably, a diminution in the size of these tumours from faradisation of the spleen itself, greatest in the first sitting, less in those following. Mader also saw good results in two cases.

There is no doubt that splenic tumours, especially malarial, and less often leukæmic, can be diminished by means of cutaneous and percutaneous faradisation of the spleen and neighbourhood (no definite results have yet been seen from the galvanic current); and this remedy is, therefore, to be recommended, probably in combination with other treatment—quinine, eucalyptus, &c.—in all cases in which the tumour displays an obstinacy and resistance to ordinary methods, as in malaria, chronic tumours after typhoid, &c.

I must not omit to mention that the attempts to influence the paroxysms of intermittent fever by the galvanic or faradic current have been unproductive of results, and do not, at all events, encourage imitation.

DISEASES OF THE THORACIC ORGANS.

The electrical treatment of the lungs and heart has as yet been tried only in a very few varieties of cases, and there is very little to say about it. Setting aside Bastings's undertaking to improve and cure pulmonary consumption by strengthening the muscles of inspiration by means of faradic gymnastics—a method which was subsequently lauded by Schwalbe—there remain only a few disturbances of the respiratory and circulatory organs, for the most part nervous in character, which have given occasion for electrotherapeutical attempts.

The first is *asthma nervosum.* It is true that in the uncertainty of our views as to the actual nature and seat of asthma, there is no little difficulty in the choice of the position and the mode of application of the electric currents. Whether it depends on a spasm of the bronchial muscles or of the diaphragm, or on a vasomotor swelling of the bronchial mucous membrane; whether on a disturbance in the domain of the vagus or the sympathetic, either a direct stimulation of these tracts or a reflex outbreak of asthmatic processes; and, finally, what point is the actual seat of this direct or reflex irritation—all this is still more or less uncertain, and probably varies in different cases. The more recent views particularly, on the specially frequent outbreak of asthma from excitations which proceed from the nasal mucous membrane and the laryngeal and tracheal structures, are not yet so generally accepted and proved that they can serve without anything further as a basis for electrotherapeutic treatment.

We are, therefore, still restricted, for the most part, to an empirical experimentation, guided too much by special views on the subject. From the few published observations, however, it is shown that with electricity, and with very different methods of employing it, unquestionable results have been obtained in bronchial asthma. Caspari has cured a case of several years' standing with the galvanic current, the kathode being fixed over the sacrum, while the anode was drawn slowly along the spinal column from the neck to the lumbar vertebræ, for 10 or 20 minutes at a time; cure after 25 sittings. Brenner saw considerable relief in a severe case of asthma from the application of the galvanic current to the pneumogastric (anode on the nape of the neck, kathode between trachea and sternomastoid). Neftel has treated a series of cases galvanically in a systematic manner, and has obtained surprising results. Proceeding on the assumption that asthma depends only upon an affection of the pneumogastric, he has made this nerve the principal object of his treatment, after the polar method; and the action of the anode on the pneumogastric was brilliantly successful in most cases, and so in some was the kathode, which was particularly effective in checking the individual attacks. Neftel begins with a weak current, increases it by the help of rheostats until the attack is diminished, and then leaves off again gradually. The sittings last from 2 to 10 minutes, at first daily, afterwards less often. Schmitz also employed the galvanic current in a case of asthma with emphysema, in which the attacks were always ushered in by extreme nasal and bronchial catarrh. Striking results were obtained—immediate relief to the breathing, with copious expectoration—by placing the electrodes on each side of the thyroid cartilage at the inner margin of the sternomastoid. Schäffer declares, contrary to these experiences, that the galvanic current in the treatment of asthma has uniformly failed him, while he has seen brilliant results from the employment of the faradic current. He regards it as a chief means of cutting short an attack, finding that frequently the most severe asthmatic breathing disappears as if by magic. Carrying out his view, that asthma occurs most frequently through irritation of the nerves in the upper part of the respiratory tract (nose, pharynx, larynx, trachea), he places the electrodes of the faradic current higher or lower according to circumstances, either close under the angles of the jaw or on a level with the thyroid cartilage, and passes a powerful faradic current for $\frac{1}{4}$ to $\frac{1}{2}$ an hour; the difficulties of breathing diminish at once, and the patients can go about easily. This is done twice daily, afterwards less often and for shorter periods. Schäffer has cured a number of cases in this way, and Bresgen, also, has seen good results from the same method.

You see, gentlemen, that we can scarcely obtain a firm basis for the electrical treatment of asthma from so few facts. The treatment of the fundamental cause must of course in all cases be first carried out, and then that of the other accompanying symptoms (nasal catarrh, polypi, emphysema, &c.), and only where you have occasion to assume a purely nervous asthma may you immediately and exclusively try electrical treatment. In other cases you may employ electricity as a palliative, along with other remedies. The simplest plan is to begin with faradic treatment after Schäffer's method; and you may at the same time faradise experimentally through the chest, and from the nape of the neck to the cardiac region and the root of the lungs. If this fails, it seems to me advisable to proceed to the galvanic current, to the treatment of the pneumogastric and sympathetic in different ways, first the action of the anode, then of the kathode, or a descending stabile current from the nape of the neck to these nerves and to the cardiac region; subsequently Caspari's method. In any case, give each of these attempts a sufficient time of trial.

Only further and more numerous observations can, however, decide upon the value of the several methods of application, and the special indications for them.

The way in which angina pectoris may be treated electrically has been already described in Lecture XXVII., p. 539.

Motor disturbances of the heart, in so far as they are of nervous origin, were for a long time seldom made the subject of electrotherapeutic treatment; at least there is not much made known on the subject. It may, perhaps, be different in future, since the publication of von Ziemssen's work on the electrical irritability of the heart.

It would in any case not be irrational to try the effect of electricity for the nervous palpitation which is so frequent. Flies is the only one who seems to have made this attempt in a large number of cases. In 24 cases, only 5 of which had shewn organic lesion of the heart, he found regularly a diminution of the symptoms; and in many cases, with no organic lesion, complete cure in 5 or 6 sittings. His method consisted in the application of moderately powerful galvanic currents to each pneumogastric for one or two minutes daily; and the descending current was said to be more effectual than the ascending. The effect was at first only subjective, but was very soon also objectively appreciable in the diminution of the frequency and intensity of the heart's action. I have myself treated galvanically a case of severe palpitation with irregularity of the heart and well-marked cardiac asthma, probably depending on organic disease, with relatively good palliative results (acting on the pneumogastric in the neck, from the nape to the cardiac region). I have not heard of any other similar observations.

It is of course quite reasonable to appeal first to the inhibitory action of the pneumogastric, and to stimulate the nerve by the current; but whether there are not cases in which the same result could be obtained by a depressant action on the cervical sympathetic, or on the excito-motor centre in the cord (anode stabile on the cervical portion of the cord), can only be determined by further experience.

Further, however, the direct action of galvanism on the intracardiac nerves may be tried according to von Ziemssen's process, sending very strong currents from the spinal column to the cardiac region, with very large electrodes and with regularly recurring reversals of the current, in order to regulate the beats of the heart. An increase in the frequency of the pulsations can easily be induced by these means, but to cause a diminution, very considerable strength of current is necessary, at least in normal hearts, although it may be different under pathological conditions. It is unnecessary to say that great caution must be used in such experiments, but they always promise certain results.

It also appears justifiable to make the same trials in debility and irregularity of the heart. Von Ziemssen's method should here again be first employed, especially the stabile passage of strong galvanic currents through the heart (without reversal of the current), which, when carried out from a particular point—the auriculo-ventricular furrow and its neighbourhood—causes an acceleration of the heart-beats in a regular rhythm, probably from direct irritation of the cardiac ganglia. Further, galvanisation of the cervical spinal cord and of the sympathetic may be resorted to; and the methods of carrying it out must be determined empirically, according to physiological rules.

LECTURE XXXVI.

Diseases of the Digestive Organs—Paralysis of Deglutition—Neuroses of the Œsophagus—Diseases of the Stomach—Nervous Vomiting—Cardialgia—Nervous Dyspepsia—Electric Methods of Treatment—Atony and Distension of the Stomach.

Diseases of the Intestine—Nervous Enteropathy—Enteralgia—Atony and Paralysis of the Intestinal Muscles—1, Occlusion of the Intestine from Atonic Fæcal Accumulation — Pathology — Cases — Methods of Electric Treatment—Invagination of the Intestine—2, Chronic Constipation from Atony of the Intestines—Cases—Percutaneous Faradisation—Recto-abdominal Faradisation—Galvano-Faradisation—3, Prolapsus Ani—Paresis of the Sphincter Ani—Ascites, its Faradic Treatment.

The abdominal organs are in many ways more suitable for electric treatment than others, being to some extent muscular, and therefore more accessible to the influence of the electric current. There are also many lesions of another nature—sensory, vasomotor, secretory, and otherwise—which present themselves as objects for electrotherapeutics.

Our interest concentrates itself first and principally on

Diseases of the Digestive Organs,

especially of the digestive tract itself in its different sections, the greater and smaller glandular appendages having much less significance for us.

Some subjects belonging to this section have been already discussed, as, for example, the frequently occurring forms of paralysis of deglutition and its treatment (vide Lecture XXV., p. 488).

Spasm and paralysis of the œsophagus alone are very rare pathological occurrences, but may occasionally become the subject of electrical treatment, which must be carried out according to general rules, with whatever modification may be suitable to local circumstances. It can be best accomplished by passing one electrode (a bougie with a metallic knob) into the œsophagus itself at various heights, the other electrode being placed on the nape of the neck, the dorsal vertebræ, or the sternum. Galvanism and faradisation may be employed, but it is advisable to be very cautious in choosing the strength of the current, on account of the proximity of the vagi, whose over-stimulation might easily have dangerous consequences.

Brenner ('Unters. and Beob.,' ii. p. 80) has cured rapidly a peculiar sensory neurosis of the œsophagus, a kind of heartburn without any other dyspeptic symptom (vagus neurosis?), by the application of the galvanic current to the region of the pneumogastric, the anode being on the nape of the neck and the kathode between larynx and sternomastoid for 3 minutes at a time, with a few interruptions.

The experiments and investigations on electrotherapeutics in diseases of the stomach are more numerous and important. I have already spoken of the fundamental physiological experiments (p. 123 et seq.) Their somewhat scanty results have not been much increased by the work of Bocci, which I have since become acquainted with. He found that direct irritation of the gastric mucous membrane with the faradic current induced distinct contractions, while an indirect irritation through the abdominal walls caused only unimportant contractions of doubtful therapeutic value. On the other hand the direct internal application of the faradic current, by means of a suitable sound, provoked, besides contractions, also injection of the vessels and a copious secretion of gastric juice.

Among pathological conditions, functional diseases, nervous and muscular disturbances of the gastric function, are, of course, exclusively to be considered. It would not occur to anyone to treat a gastric catarrh, an ulcer, or a tumour of the stomach with the electric current, although it promises many results in those conditions which depend on a diseased condition of the sensory gastric nerves, on spasm or weakness of the muscles, or, finally, on insufficient action of the nerves of secretion. There are, indeed, already a number of observations on all these subjects.

Several observers (Semmola, Lente, Popper) have found the galvanic current useful in nervous vomiting, as it occurs in hysteria, in pregnancy and in childbed, in migraine, dysmennorrhœa, &c. The methods of administration are more or less empirical, either faradisation of the neighbourhood of the stomach, from the back or from the nape of the neck to the epigastrium (Lente); or both poles on the gastric region, with large electrodes and tolerably strong currents (Popper); or galvanism in the same manner, finding out by experiment whether the anode or the kathode is more useful in the epigastrium. The galvanisation of the neck and of the cervical portion of the cord, however, appears to be specially efficacious, and by this means the most implicated nerves, pneumogastric, sympathetic, phrenic, and the centres in the medulla oblongata, are the most quickly influenced ; and it is at least advisable to galvanise from the neck to the gastric region (Semmola). The published results are in part very brilliant ; in most cases improvement is felt at once.

The treatment of *nervous cardialgia* has been already described in Lecture XXVII., p. 541.

The so called *nervous dyspepsia* has a special interest in recent times, and several voices have already been raised in favour of its electrical treatment. Certainly the different views on what is called 'nervous dyspepsia' are by no means clear. If, with Lente, we were to regard as such only those cases in which, with a digestion normal in duration and in chemical results, various disagreeable and painful local or general symptoms occur during the process, whether from abnormal irritation of the gastric nerves themselves or from abnormal excitability of the general nervous system, the range of 'nervous dyspepsia' would, in my opinion, be too narrow. For there are undoubtedly cases in which a digestion abnormal in duration and in chemical results may proceed from the nervous system, through deficient innervation of the glands of the stomach, or through an insufficient activity of its muscular coat, without any alteration in the structure of the stomach, and give rise to the symptoms of 'nervous dyspepsia.' In the one series of cases the neurodyspeptic disturbances proceed from a digestive process normal in itself, while in the other series the process itself becomes abnormal from primary nervous disturbances. Both forms are closely allied to each other, however, and can certainly not be separated so exactly in practice as in theory; and the electric current is a suitable mode of treatment for both, along with other remedies, indicated by the general condition of the patient.

The diagnosis of the condition is by no means always easy, but with accurate observation and investigation, by the exclusion of organic lesions, not seldom also *ex juvantibus et nocentibus* (aggravation of the symptoms by Karlsbad and other cures), you will often be able to recognise it with certainty. In any case it is much more frequent than has hitherto been supposed, and among the numerous neurasthenics there are many with this nervous dyspepsia. Perhaps the symptom recently mentioned by Burkart (who has furnished a valuable work on this subject), viz. tenderness on pressure over the abdominal sympathetic plexus, may supply a certain indication for the recognition of the affection.

In the electrical treatment you may use both currents, and may employ them in different ways, according to the most prominent existing symptoms. Beard and Rockwell, who first elaborated the electrical treatment of nervous dyspepsia, recommend in the first place *general* faradisation, and rightly so, since in most cases the patients are suffering simultaneously from general neurasthenia. The stomach is directly treated at the same time. Galvanism of the pneumogastric and sympathetic and of the spine, and later central galvanisation, are also to be recommended. Leube employs partly strong faradic currents (from the back to the epigastrium), partly the galvanic current, almost always externally, the anode on the epigastrium, the kathode on the dorsal vertebræ, with tolerably powerful currents. The internal application, by means of a gastric electrode, does not seem to him to be more effectual than this method. Burkart saw splendid results from the employment of the galvanic current in a similar manner: he presses the anode as deeply as possible into the region of the tender abdominal plexus, and applies the kathode to the back with a stabile current. Stein, again, prefers the faradic current, and passes it, in medium intensity, with large flat electrodes, straight through the abdomen, from one hypochondrium to the other. Richter mentions electricity among the remedies for nervous dyspepsia, and Kussmaul saw good effects from faradisation of the abdomen in various forms of the affection. I myself have collected very few facts on this special subject, but I have no doubt that electrotherapeutics will frequently have the best effect in the different forms of nervous dyspepsia. The faradic current should perhaps be tried first, especially where atony of the stomach and intestines is conspicuous; and if the abnormal sensations, hyperæsthesia of the gastric nerves and the like, are predominant, an attempt with the galvanic current would be justifiable (anodic action), especially if the tenderness on pressure of the abdominal plexus is marked. The faradic and galvanic currents may also be used alternately. The customary methods of treatment for neurasthenia in general are also to be tried, and in all obstinate cases the treatment of the pneumogastric and the sympathetic in the neck, and along the spinal column, subsequently also central galvanisation and general faradisation, must not be omitted.

Atony and dilatation of the stomach are often observed in the closest connection with this nervous dyspepsia. It is obvious that these lesions are specially favourable for electrical treatment, which is indeed the most important remedy for all conditions of motor weakness.

Atony of the stomach is a very common occurrence in all diseases of the nervous system, especially in general nervous weakness and in many central nervous affections. It may also come on in consequence of chronic gastric affections, in long-continued and frequently repeated over-loading of the stomach with bulky food, and the like. When it has lasted for some time, it leads as a rule to dilatation of the stomach, and that, again, can be referred back to various pathogenetic causes.

There are cases of traumatic origin from a blow or fall on the epigastrium, especially in nervous, hysterical persons; others which arise in consequence of gastric catarrh and subsequent atony of the muscular coat; and others from overloading of the stomach with food, or distension by gas or stagnation of the ingesta, the last-mentioned forms being specially frequent where there is stenosis of the pylorus from any cause.

In all these cases, electrical treatment may be tried for the purpose of exciting gastric contractions and of removing the atony, which is in all circumstances the first step towards relieving the distension. It is unnecessary to say that other remedies (especially the stomach pump) deserve attention, and that the causal indications must be fulfilled. But even in such cases electricity may be used as a help to other treatment, and it is the sovereign remedy in cases of purely nervous atony and ectasia of the stomach.

The methods recommended by the several authors are not identical. Onimus recommends the galvanic current (from the back to the epigastrium, and from the lesser to the greater curvature), and whilst Leube only mentions briefly that he has seen good results from the galvanic current, nearly all the other authors prefer the faradic, which seems also to me to be the most suitable for the desired end of exciting the unstriated muscular fibres of the stomach to increased peristaltic action. Fürstner places one electrode in the left hypochondrium, the other in the gastric region, and moves it with strong pressure from the cardiac orifice to the pylorus in an intermittent manner, with a powerful current. Neftel places both electrodes on diametrically opposite points of the surface of the distended stomach, and sends increasing induced currents through the different diameters 10 or 20 times in succession; or he passes through very powerful currents 15 or 20 times for only a few seconds at a time. Oka and Harada place the anode in the region of the cardiac orifice, whilst the kathode is moved firmly over the gastric region for about 10 minutes, preferably before the principal meal of the day.

Having regard to the anatomical relations of the parts, it seems to me most effectual to place one large electrode on the back, close to the spinous processes on the left side, on a level with the cardiac orifice, whilst the other electrode, smaller in size, is applied first to the epigastrium, and then successively to the other points of the entire gastric surface, the current being so strong as to cause active contraction of the abdominal muscles. With the galvanic current, the anode is to be applied to the back, and the kathode, labile, over the stomach. The sittings should be daily, and should last from 3 to 8 minutes. It seems specially advisable to use the electricity immediately after washing out the stomach by means of the stomach pump.

You will seldom have occasion for the internal employment of one electrode by means of a sound; at all events, the observations that have already been made on the subject do not speak decidedly in favour of it. On the other hand, a proposition made by de Watteville for 'galvano-faradisation' (p. 253), the simultaneous action of the galvanic and faradic currents on the irritated parts, appears to me to be specially suitable for these conditions of atony and weakness of the muscular coat. This procedure is worthy of being tried oftener in such cases, as it will presumably be more efficacious than the alternating or successive application of the galvanic and faradic currents. The method of application is exactly the same as with the faradic or galvanic current alone.

I would also add that, in those cases of atony of the stomach, a trial might be made of galvanisation of the pneumogastric and sympathetic in the neck, and also of the region of the division of the splanchnics from the dorsal sympathetic (5th to 10th dorsal vertebræ).

But on all these things light can be thrown only by further therapeutic researches, which will certainly not be wanting in view of the increasing interest which these nervous gastric affections have been recently exciting.

The electrotherapeutics of the intestines have been moving in the same direction as those of gastric affections, and here also it is principally the functional, nervous disturbances which have been the subject of electrotherapeutical researches.

Nervous enteropathy, which generally forms part of the symptoms of nervous dyspepsia, and expresses itself in a different way only because of its different localisation, is treated in the same manner and with the same results, according to the views of Burkart, Richter, Stein, and others. The application of the current will, of course, have to be made more in the region of the intestines and of the hypogastric plexus.

I have already shown that *nervous enteralgia* is suitable for electric treatment (Lecture XXVII., p. 542), and have said that in lead colic especially we can act on the pain as well as on the constipation by means of the faradic current.

But by far the most important is unquestionably the employment of electricity for exciting peristaltic action, in all conditions of atony, up to complete paralysis of the muscular coat. Those frequent and troublesome affections form very grateful subjects for electric treatment; we must, however, distinguish two forms.

1. *Occlusion of the intestine from atonic accumulation of fœces.* In these cases, after previous sluggishness of the bowels, more or less obstinate, suddenly, from indigestion, overloading of the stomach, intestinal catarrh, or the like, complete obstruction sets in, with great fæcal accumulation, intense meteorismus, acute pain, and often with very threatening symptoms, which may even amount to those of ileus. It is of course difficult to distinguish this from other forms of obstruction of the bowels (from invagination, internal stricture, twisting, &c.); but the previous constipation, the presence of masses of fæces, the continued absence of fever, perhaps a former similar attack, will aid the diagnosis. Besides, electrical stimulation of the intestines will do no great harm in the other forms of occlusion, and it is distinctly contra-indicated in well-developed peritonitis only. Indeed Curci recommends electricity as a means of differential diagnosis in just such cases of intestinal obstruction from obscure causes: if one or two sittings cause neither evacuation nor relief, a mechanical obstruction is to be suspected.

A whole series of observations, chiefly from abroad, show that in such acute cases, after all purgative remedies have been employed in vain, and the symptoms have assumed a threatening intensity, the energetic use of the electric current suffices to stimulate peristaltic action, and to induce evacuation and thereby recovery.

163. *Observation by Hofmann. Typhlitis Stercoralis. Paralysis of the Muscular Coat of the Intestines. Ileus.*—In a woman of 72, after continued constipation, meteorismus, foul eructations, and, finally, frequent vomiting with fæcal odour set in. Purgatives and enemata were useless. Faradisation of the intestines, one pole in the rectum, the other in the right iliac region, with a powerful current, for a quarter of an hour, caused an evacuation of fæces and recovery.

164. *Observation by Mario Giommi. Obstinate Constipation.*—Cure by faradisation. A robust peasant, aged 51. Was seized on July 22 with pains in the abdomen, which was followed at first by a few scanty evacuations, and afterwards by obstinate constipation, which defied all remedies. On August 8 he was admitted into hospital. Great pain, intense meteorismus, circumference of abdomen 99 centimetres (39½ inches), much eructation of odourless gas, difficulty of breathing, dry tongue, &c. Percussion note resonant. An old scrotal hernia could be certainly excluded as a cause of the attack, and simple atony of the muscular coat of the intestines was diagnosed, and the employment of electricity decided on; injections of water, colocynth, and nux vomica having been previously tried in vain. Faradic treatment: One electrode in the rectum, the other on the abdominal wall over the transverse colon, with the strongest current obtainable. First sitting 15 minutes; no result. Next morning second sitting for 20 minutes; scanty evacuation of yellowish masses, condition of patient somewhat worse; in the evening, after the third sitting, two copious evacuations with much discharge of gas, circumference of abdomen reduced to 82 centimetres (33 inches). After the fourth sitting further evacuations, and then progressive advance towards recovery. Discharged September 2. Circumference of abdomen 72 centimetres (29 inches).

165. *Observation by J. Simon (communicated by Ballouhey). Severe Intestinal Obstruction. Colic and Ileus.*—Rapid recovery by means of electricity. A man, aged 44. Was seized on June 15 with sudden vomiting, combined with acute colicky pains; no fever. Obstinate constipation followed, with increasing pain, and meteorismus gradually developed. Enemata and all kinds of purgatives useless. No hernia, no mechanical cause discoverable. Increasing distension of abdomen, anxiety, obstinate constipation, repeated vomiting, quick thready pulse, anxious expression of countenance. The symptoms increased in intensity until, on the evening of June 17, the employment of electricity was decided on, and was carried out by Dr. Onimus. Faradisation of abdomen and intestines, alternating

with labile galvanic current, for 20 minutes. The vomiting ceased immediately, and two fluid stools ensued. Some improvement. After three hours a second electrical sitting, followed in the night by 12 stools and abundant passage of gas from the rectum. No more vomiting, and diminution of oppression. On June 18 continuance of the fluid stools, less tenderness of abdomen, no more nausea, no fever. Undisturbed convalescence.

Most authors employ exclusively the faradic current for such cases (Duchenne, Hofmann, Mancini, Santopadre, Curci, Chouet, Giommi, Scarpari); Wharton only has used the galvanic current, and with good results: he introduces one pole into the rectum, places the other on the sacrum, and passes a current of 14 elements for 10 minutes, with frequent reversals. In the faradic treatment also one pole is introduced into the rectum (Curci alone appears to have confined himself entirely to an external application), while with the other (kathode) the whole abdominal wall, but especially the region of the cæcum and the rest of the large intestine, is successively stroked with a very powerful current, so that energetic contractions of the abdominal muscles take place. Length of sitting, 5 to 20 minutes. Ballouhey describes, according to the practice of Onimus, a mixed procedure: first the percutaneous labile use of the galvanic current on the abdomen, with the anode as near as possible to the point of obstruction; then recto-abdominal faradisation in the usual way, and, finally, recto-abdominal galvanisation (kathode in the rectum) with frequent interruptions; this cycle to be repeated several times in one sitting. De Watteville's galvano-faradisation might also be tried in such cases.

Boudet's method for all forms of intestinal obstruction is the following, based on theoretical grounds, which are well worthy of consideration: Galvanic current; one electrode, fastened in a thick indiarubber sound, introduced into the rectum, which has been filled with 1 litre of salt and water, while the other (400 sq. centimetres in diameter) is placed on the back. The current should have a strength of 10 to 50 ma., should be stabile, and should act from 5 to 20 minutes, or it may be reversed several times with pauses between. A few applications are said to produce a good result. Rapin has also been uccessful with this mode of treatment.

The sittings may be repeated with advantage two or three times daily, until improvement takes place. This shows itself by the discharge of gases, and by more or less copious, often enormous evacuations from the bowels, which sometimes follow immediately upon the faradisation, but generally not until one or more hours after. This procedure, which has been almost entirely neglected in Germany, certainly deserves a more extended investigation.

Finally, I would mention that Bucquoy has successfully treated invagination of the intestines, as it occurs most frequently in children, with the faradic current, after exactly the same manner. He expects retrogression of the invagination by means of the excited peristaltic action, but advises that the electricity be employed early, and before any inflammatory complication has occurred. It is borne well even by infants, and two or three sittings of ten minutes each usually suffice to induce an evacuation and relieve the invagination. Of course other treatment must not be quite neglected.

2. *Chronic constipation from atony of the intestines* is a very frequent, even daily occurrence. It is very commonly observed in nervous patients of all kinds, hysterical, hypochondriacal, neuræsthenic, with or without the accompaniment of nervous dyspepsia; in nearly all spinal affections, myelitis, tabes, &c., and in many cerebral diseases, epilepsy, &c. It is specially common among women, in whom it is often caused by unsuitable ways of living and eating, want of exercise, too strongly seasoned food, &c., and sometimes also to a great extent among young girls at the time of puberty. It is further found in consequence of chronic intestinal catarrh, hæmorrhoids, chronic peritonitis, &c., and, finally, one very important cause is the widespread misuse, or too long continued employment, of purgatives, especially of the more drastic remedies.

Every pathologist of any experience, and certainly every neuropathologist,, knows how wide-spread and how troublesome this affection is, how it resists any attempt at cure, and how much it aggravates a whole series of symptoms, especially in functional neuroses. All symptoms of a decided intestinal disease may be wanting; there is a simple indolence of the bowels, caused by deficient peristaltic action, from atony of the intestinal walls. It is at the same time possible that a diminished secretion of intestinal juices may have an aggravating influence on the affection.

Electricity is an admirable remedy in such cases, and I can entirely confirm the favourable results reported by Benedikt, Scarpari, Günther, Stein, and others of the electrical treatment of atonic constipation.

166. *Personal Observation. Epilepsy. Severe Constipation.*—A student, aged 20, suffering from severe epilepsy, and from such a degree of constipation that for several years he had had an evacuation only from the employment of powerful purgatives, had his bowels so regulated by systematic faradisation of the intestines for several weeks that years passed without any necessity to resort to any remedies beyond an occasional enema.

167. *Personal Observation. Cephalæa Nervosa. Habitual Constipation.*—A girl, aged 19, who suffered from severe nervous headache and other neurasthenic troubles, and from a high degree of habitual constipation, was relieved of the latter to a great extent by the employment of regular faradisation of the intestines; the faradic current certainly proved far more effectual than all the other vainly tried purgative remedies.

168. *Personal Observation. Gunshot Wound of Abdomen and Vertebræ. Obstinate Constipation.*—An officer, aged 26. Received on August 30, 1870, a shot in the abdomen, which entered anteriorly in the right hypochondrium, and emerged posteriorly by the left side of the fourth lumbar vertebra. Complete paraplegia, including the sphincters, ensued. In the course of the winter gradual improvement: left leg regained power, the right below the knee completely paralysed and atrophic, with RD. A great deal of neuralgic pain, sleeplessness, retention of urine. During the whole time the patient never had a spontaneous evacuation, except when diarrhœa was present from any cause; castor oil and enemata had to be constantly employed. In June 1877 galvanic treatment of the paralysis began, the patient complaining that the castor oil was gradually losing its effect. July 5, stoppage of the bowels; percutaneous faradisation of the intestines; during the following night copious evacuations without purgatives. July 6, no faradisation. July 7, scanty stool; second faradisation. July 8, normal stool; faradisation. July 9, stool in the morning; faradisation, tolerably powerful, in the afternoon, followed shortly after by copious evacuations. July 10, no stool in the morning; faradisation in the afternoon, followed by stool. July 11, stool in

the morning; faradisation; copious stool in the evening; chill during the night, and on July 12 spontaneous diarrhœa. July 13, no stool; faradisation. July 14, copious stool, and so on. On July 23 the patient left for Wildbad, and reported on his return that the stools were much better, and that purgatives were seldom necessary, in spite of the regular administration of large doses of morphia.

169. *Personal Observation. Obstinate Constipation in Consequence of Peritonitis.*—A student, aged 23. Had a severe and tedious perityphlitis, with pericystitis, &c., during the previous winter; had suffered constantly since then from constipation, treated with pil. visceral. and enemata; frequent abdominal pain, and slight inflammatory irritation. No spontaneous evacuations, except when diarrhœa was present. Was treated faradically from July 9 (percutaneous faradisation of the intestines). The pills were discontinued. From the first day, with few exceptions, regular spontaneous evacuations occurred, either in the afternoon, soon after the faradisation, or on the following morning. The treatment was continued with the same good results until August 23, enemata being necessary only now and then. The pain and dyspepsia decidedly diminished; the improvement lasted for some months, and it was later definitely established by a repetition of the same treatment.

170. *Observation by Stein. Habitual Constipation.*—An English girl, aged 18. Never before ailing, had menstruated regularly for four years, and had suffered during that time so much from constipation that she never once had a stool without purgatives. Loss of appetite, and much mental depression. Faradisation, moderately strong, for ten minutes transversely through the abdomen. At first this was followed by spontaneous evacuations at intervals of two or three days, but from the 19th sitting onward they occurred regularly every day. After 28 sittings, the later ones being made at longer intervals, the cure was complete; since then the patient has looked blooming, with a good appetite and cheerful spirits.

Compare also the other observations of Stein's, and Obs. 111, p. 542 (lead colic).

The electrotherapeutic methods employed for this habitual constipation admit of a gradual intensification, according to the severity and obstinacy of the case.

I generally begin with the percutaneous employment of the faradic current, recommended by Benedikt.[1] The anode

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[1] The recent physiological researches of Fubini are also in favour of the faradic current.

('large' electrode) is placed on the upper lumbar vertebræ, while the kathode ('medium' electrode) is slowly passed over the whole abdominal surface. It is pressed more firmly on the cæcal region, and may even be left stabile there for a little time; it is then passed along the colon to the left iliac region, where it is again pressed in more deeply, in order to act specially on the sigmoid flexure; then passed round the umbilicus, and in spirals or circles over the entire abdomen. The current should be tolerably strong, so that powerful contraction of the abdominal muscles may be excited. It seems advisable, however, to avoid these contractions as much as possible, because they interfere with the passage of the current into the deeper parts; it is better to press the electrodes deeply into the abdominal walls, at a distance from the motor points, especially in the flanks. The duration of the whole application should be from three to ten minutes. In addition, I sometimes pass a current transversely from one hypochondrium to the other, with reversals, the electrodes being pressed as deeply as possible into the flanks.

For a more powerful effect, I then add the intrarectal application of one electrode, whilst the other is passed over the abdomen in the manner above described. An olive-shaped, metallic electrode, insulated as far as the head, is introduced 6 or 8 centimetres (2½ to 3 in.) or more into the rectum; it causes no sensation, or, at the most, when the *kathode* is in the rectum, a slight prickling and burning. It is advisable to reverse the current several times, in order to bring the more strongly stimulating kathode to act on the rectum. The energetic contractions of the abdominal muscles serve as a measure of the strength of the current; the sitting should last from three to ten minutes. (If this procedure is carried out with the galvanic current, prolonged closure of the circuit must be avoided, to prevent the formation of eschars; it is best in such a case to change the current frequently, with very short periods of closure.)

If this treatment is not sufficient, I precede it by an application of the galvanic current directly to the abdomen (anode on the back, kathode stabile and labile with repeated closures and changes of polarity, along the whole extent of the intestine); and, further, to the region of the splanchnics in the thoracic sympathetic (anode on the sacrum, kathode stabile and labile on each side of the spinous processes, from the 5th to the 12th vertebræ), which need only last for a few minutes. The efficacy of the subsequently employed faradic current will thereby be much increased.

The galvano-faradisation recommended by de Watteville will presumably be still more effectual for this purpose; the electrodes, containing both currents, are arranged and manipulated in the same way as has been explained for the simple faradic treatment (anode on the back, kathode on the abdomen). It is to be expected that this will greatly surpass in efficiency the simple faradisation.

By these various methods of treatment, improvement in the atony of the intestines and in the constipation is generally seen very soon; the purgatives, which at the beginning are still necessary, become more efficacious, soon the dose can be diminished, then a spontaneous stool takes place now and then, and gradually the purgatives can be dispensed with or reduced to a minimum, and so a cure be effected. This has also a very favourable influence on the spirits and general condition of the patients. I need scarcely say that there are some forms of habitual constipation which resist all electrical treatment.

Blackwood reports good results from a ‘galvanic suppository’—a conical piece of zinc in the anus (perhaps with a small enema of salt and water), and a tongue-shaped plate of silver in the mouth, connected with the zinc by means of an isolated wire. It is said to be sufficient to apply this for 5 or 15 minutes before an evacuation is desired, or for a quarter of an hour night and morning. Otherwise Blackwood regards faradisation, in combination with massage of the abdomen, as the best remedy for habitual constipation. Hünerfauth reports good results from the same means, combined with hydropathy, and faradic baths, according to Lehr, are very useful.

3. *Prolapsus ani* and *paresis of the sphincter ani* may also be mentioned as the last forms of disease belonging to this category, observed as they are, especially in infants, in conse-

quence of costiveness and weakness, in adults from hæmorrhoids and obstinate constipation, from severe straining at stool, and not unfrequently also as a sequence of spinal and peripheral paralysis. Good results have been obtained from the electric current, especially in the varieties conditional on atony of the sphincter (Duchenne), while the prognosis of sphincter paralysis, dependent on spinal disease, must be considered, of course, in relation to the fundamental affection.

Faradisation of the rectum is indicated here by means of the rectal electrode, which must be introduced just inside the opening, to induce direct irritation of the sphincter, which causes a considerable amount of pain. You may, further, stimulate the intestine and the sphincter by means of the galvanic current, either with the rectal electrode, or percutaneously from the sacrum to the perineum, or, lastly, the nerves of the plexus sacralis may be stimulated in the usual way. The electric treatment of the fundamental affection may also be considered.

In conclusion I will mention that *ascites* has also been repeatedly the object of electrotherapeutical researches, and not without good results. Solfanelli, Alvarenga, Glax, Sigrist, and Popow have treated such cases and reported on them. The ascites had been caused sometimes by cirrhosis of the liver, sometimes by malarial cachexia, vitium cordis, emphysema, general anæmia, &c. The treatment consisted, in all cases, in the energetic faradisation, for 10 or 15 minutes, of the abdominal walls (in the same manner as I have stated with regard to atony of the intestines), and Glax and Sigrist both lay special stress upon the frequently repeated excitation of the several motor points of the abdominal muscles, each of which should be thrown into short contractions 50 to 100 times in a sitting. The results were surprising in most cases; with increase in the amount of urine passed, the ascites diminished, and its complete disappearance could be attained in a short time; the duration of the cure, however, is of course dependent on the primary disease. The opinion of Glax, that only the mechanical action of the contracted abdominal muscles is the agent in the cure, will not suffice as an explanation of the result; we must certainly consider also the vasomotor and katalytic action of the current, the favourable influence on the penitoneal vessels, the increase of the blood pressure, and the stimulation of the renal secretion. Further researches and more exact investigations on this point are much to be desired in the interests of general electrotherapeutical questions.

XII. *DISEASES OF THE GENITAL AND URINARY ORGANS.*

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LECTURE XXXVII.

Affections of the Bladder—Introduction—Spasm of the Bladder—Its Treatment, Direct and for Removal of the Cause—Paralysis of the Bladder—Its different Forms—Pathology—Treatment as to Cause and Symptoms—External and Internal Applications—Galvanisation of Cord in Lumbar Region—Results.

Affections of the Male Organs of Generation—Inflammation and Hypertrophy of the Prostate—Orchitis—Functional Disorders—Impotence—Emissions—Spermatorrhœa—Aspermatism—Their various Pathology—Treatment as to Cause and Symptoms—Results.

Affections of the Female Sexual Organs—Introduction—Menstrual Disorders—Amenorrhœa—Dysmenorrhœa—Menorrhagia—Chronic Metritis—Uterine Displacements—Arrest in Secretion of Milk.

Final Observations—Contra-indications to the Use of Electricity—Phenomena connected with the Organs of Circulation and the Influence of the Nervous System.

In conclusion, gentlemen, we have entered upon an extensive and complicated field of study. Disorders of the urinary and genital organs are extremely common not only in connection with nervous diseases but in various others, and assume the most serious aspect whether in the course of a malady or in the ordinary processes of life. The medical man, and more particularly the specialist, are very often called upon to concern themselves with these questions, with reference to which electrotherapeutics have long since been recognised as of great importance. Still I am compelled to sum up in a few words and not to treat too diffusely this subject, interesting though it is, and yet obscure in many of its relations. Much of it is sufficiently clear after what has been already said, and needs but a short and passing allusion. The question of greatest importance in this connection is that of the bladder. The functional disorders of that organ are very common, both as sequelæ and symptoms of nervous diseases and of local affections (seated in the *cauda equina*, sacral plexus, vesical nerves, &c.), and also in the course of spinal, more rarely in cerebral diseases. Sometimes they are localised, as a consequence of chill, abnormal distension of the bladder, or inflammation of that organ. Sometimes they are due to reflex irritation or toxic agencies, which have a powerful effect upon the mucous membrane of the bladder, so paralysing or stimulating its muscles. The circumstances, then, in which disorders of the bladder arise may vary much. Very often they exist quite independently; more often they are one expression of a complex pathological state. At other times, again, they are the distant precursors of other manifestations of some cerebral disease (tabes, myelitis, &c.) and appear but as a first strictly localised symptom.

Now for nearly all these forms of disorder, especially those which are not accompanied by inflammatory or plastic affections of the bladder, and which are not due to a mechanical obstruction having its seat in some neighbouring organs (prostate, rectum, uterus, ovaries, &c.), electrical treatment may be indicated.

No doubt this statement holds less in cases of what we call *spasm of the bladder*, or *vesical tenesmus*, which may appear in the form of spasmodic contraction of the muscular fibres, as in incontinence due to spasm; or as spasm of the sphincter, such as spasmodic retention, or spastic ischuria. In these cases it is usual to attempt by other means to alleviate the condition, especially when we are concerned with an inflammatory affection of the bladder itself. Still there are cases of spasm of the bladder which are purely nervous in their nature, and which may properly be brought within the province of electrotherapeutics. It behoves us, then, above all things to ascertain the cause of the abnormal irritation, so as to take steps to counteract it. Suppose, then, you have to deal with an affection within the vertebral canal, and in the spinal cord itself, and try to treat it appropriately. Here you need above all things to pass sustained galvanic currents through the lumbar region of the cord and the lower segments of the vertebral column; in other words, to bring the positive pole to bear actively and continuously upon the supposed seat of the mischief. (Such a case has been successfully treated by E. Koch.) Endeavour also to induce vigorous action in the skin, and in this way to bring about counter-irritation to oppose that which has induced the spasm, just as in the treatment of neuralgia. To this end apply the faradic brush to the skin at the crest of the symphysis, the perineum, the sacrum, &c.

The *direct treatment for spasm of the bladder* is effected upon the same principles as in the case of spasms in other parts; that is to say, by the sustained application of the galvanism, by opening and closing the current, by the powerful action of the anode upon the special seat of morbid irritation; and naturally this is not easily to be attained with accuracy in the case of the bladder. The best way will be to apply, with pressure, a large electrode to the symphysis, and the other immediately opposite it upon the sacrum, or preferably to the perineum. The better plan decidedly is to place the anode upon the sacrum or perineum. It will be necessary to adopt the same points for the application of the faradic current. Begin with weak faradic currents as directed, and it is only when you fail to obtain any result that you will have to resort to stronger and increasing ones and to render this application more and more prolonged.

I do not think that the urethral or rectal electrode should be used in spasm of the bladder; for their use is apt to aggravate existing irritation, and there is moreover the risk of causing wounds with the galvanic current, which in these cases has to be used in a steady and prolonged form. It will be well, then, to reject these resources; it would be much more advisable, in desperate cases, to make use of faradic currents and this internal mode of application. It is to be desired that more accurate observations upon this point should be published.

The true province of electrotherapeutics, in disorders of the bladder, is cases of weakness, of paralysis of that organ. It is a morbid symptom as common as it is insupportable, and which occurs in forms that vary from the slightest degree to the most considerable. It is chiefly in affections of the spinal cord (tabes, compression, effusion of blood, myelitis, sclerosis, &c.) that paralysis of the bladder plays a very important part, and occurs with remarkable frequency. There are in addition peripheral nervous lesions of the most varied character which attack separately the nerves of the bladder, in the *cauda equina* or in the sacral plexus and its branches. This symptom is much less common in cerebral disease. On the other hand, it is as much more frequent in hysteria, in which vesical paralysis is an event of constant occurrence. Finally, there occur cases of paralysis of the bladder of a more independent nature, altogether distinct and separate and with or without ascertained cause (chill, traumatism, shock, opium poisoning, &c.) Paralysis of the bladder may present itself in different forms. Where the muscles of expulsion are chiefly engaged we have the phenomenon of retention of urine in its different degrees; if, on the other hand, the sphincter principally is affected we have incontinence of urine more or less complete. But occasionally it happens that both classes of muscle are paralysed. The patient then cannot retain his urine, nor can he pass it at will. Here we have the act of emptying the bladder performed fully and regularly but without the control of the will—and this is where the reflex mechanism in the lumbar cord remains intact—or a constant dribbling of the urine ensues, while the bladder may still be distended by the accumulating fluid (paradoxical ischuria). We should be led to wander too far from our subject were we to consider in full the innervation of the bladder, and the different disorders which may arise in that organ throughout its various parts—in the muscles themselves, the peripheral nerves, or the lumbar cord and its presiding centres for emptying the bladder, or those remote channels, motor and sensory, through which the nerve influence of the bladder is connected with the brain and becomes lost in the spinal marrow. Therefore I would refer you for information upon this head to the text-books of physiology, or to my treatise on the 'Affections of the Spinal Cord' (1st ed., pp. 65 and 146), where I have handled these things separately and attempted to distinguish the various forms of paralysis of the bladder, according to the seat in each case of the cause of the paralysis.

It is unnecessary to say that for the rational application of electricity you must ascertain in every instance the form and seat of the disorder, the way in which it is produced, and especially the precise situation of the paralysis in the nervous system.

Then you may adopt the mode of electrical treatment suitable to each case. It is clear that you should at the outset direct your attention to the primary affection and treat it effectually and appropriately. I need not here add anything to what I have already said with reference to the treatment of affections of the spinal cord. But I would not have you believe that I look upon the treatment by electricity as the only resource for the cure of these primary affections. Quite otherwise: I am well aware that by the use of other remedies and modes of treatment much can be effected in the class of cases now under consideration, and results are often obtained that are better than can be derived from our electrotherapeutics.

In conjunction, however, with this treatment directed to the cause, and in those cases, which are not uncommon, where such treatment is impracticable, the paralysis of the bladder should be directly treated. This last mode of treatment is concerned only with the bladder and its nervous centres and connections. There are different ways of applying it, whether through the skin by means of moistened electrodes, or internally with the aid of a catheter, either the faradic or galvanic current being used. The various points where the application may advantageously be made are as follows :—

For external application, you place one pole (usually the anode) over the situation of the lumbar enlargement, upon the lower dorsal and the upper lumbar vertebræ. The other (the kathode) is laid over the situation of the bladder, and when retention is the chief trouble it is advisable to place it against the symphysis and make as much pressure as possible. If, on the other hand, incontinence is the condition to be overcome, the kathode should be applied to the perineum as nearly as possible to the sphincter and in as close contact with it as may be. In the case of women it should be used in an appropriate manner. If both classes of muscle are affected, you make use of both modes of application, or you may, as before, place one pole upon the symphysis and the other on the perineum. When you use the galvanic current, let it act freely and steadily for some minutes at the places indicated, often breaking and reversing the current. The strength of the current should be so regulated that at each kathodic closure powerful contraction shall take place in the abdominal muscles, seen to originate at their motor points. To employ the faradic method, make use of currents as strong as possible, continued for some minutes (say five or ten) at the points mentioned above, and interrupt at frequent intervals, or you can apply the so called faradic current.

For internal application, the anode is placed in the same way upon the lumbar region. A vesical electrode, made like a catheter, and insulated except at the extremity, is introduced by the urethral canal, in the case of incontinence, only to the neck of the bladder, so as directly to stimulate the sphincter, when retention is present within the bladder, which is kept full if possible, or may be filled beforehand with tepid water, holding salt in solution. Needless to say, precautions must be taken to render the catheter-electrode aseptic. In this way and using the *galvanic current* you can safely employ only short closures of the kathode, or a few reversals with the period of closure of short duration, so as not to wound the parts. The best plan will be to determine the current strength by means of the galvanometer. With the *faradic current* you can make use of currents of considerable strength, for the bladder itself is not sensitive, and the urethra in its remoter parts but little so. Here then the current, frequently interrupted, may act for a long time with a constant strength, or one that increases or diminishes in intensity. As a measure of the strength of the current we can make use of the fact that when the sphincter is faradised, it contracts with each closure of the circuit, and in consequence pushes the catheter along the urethra or expels it entirely from it. With reference to faradisation of the detrusor muscles, it is perhaps advisable, with a view to directing the current in every direction through the walls of the bladder, to place the anode upon the abdomen alternately to right and left, and in turn to the summit of the bladder and the perineum. The muscular contractions produced in this way afford a sufficient measure of the current strength. As regards internal application, you must be careful not to make the sittings too long.

Finally, there is a mode of application by way of the rectum. Here the anode (an electrode of metal shaped like an olive) is inserted within the rectum at a convenient height. The kathode is applied to the symphysis, and a galvanic or faradic current induced exactly as described above. An attempt even has been made to introduce at the same time a catheter electrode within the urethra or bladder, and in this way to stimulate the vesical muscles (Duchenne, Pètrequin, Erdmann). Since in that case we have no means of estimating the strength of the current, and further because it is only the fasciculi upon the posterior part of the organ that are effectively stimulated, this proceeding has no special advantage.

In all cases of serious and obstinate paralysis of the bladder it is my habit to resort in addition to a direct and vigorous galvanisation of the lumbar cord, with the object of stimulating directly the nerve centres of the bladder. According to circumstances I sometimes even employ a strong and persistent application of the kathode to the *cauda equina* in the situation of the coccyx and perineum, or throughout to the spinal cord as far as the cervical vertebræ.

You will, of course, make your choice amongst these different methods, according to the diagnosis and circumstances of the case. As a rule, it is well to proceed from gentler and less active measures to those of greater strength and intensity.

The results of this mode of treatment vary much in different cases. In transverse inflammation of the cord, in compression and effusion of blood they are not likely to be good. They are much better in tabes, where treatment by electricity is often a good help. They are very good, sometimes brilliant, in hysterical affections, as well as in vesical paralysis of cerebral origin; excellent too in many forms of toxic disorder and in others whose nature is not understood. But sometimes too in these cases all forms of treatment will fail of effect.

A variety of weakness of the bladder of quite a special nature is *nocturnal incontinence of urine*, known as *enuresis nocturna*. For electrotherapeutics it forms a source of excellent results.

The theories that have been framed as to the exact nature of that very common disorder have been by no means sustained by proofs, and there is still room for hypotheses of every description as to its exact seat and pathology. In my opinion the true cause consists, in the majority of cases, in a want of proportion between the sleep, which is profound, and the irritability of the distended bladder, leading in consequence to its evacuation. This explanation holds at all events for all those cases in which during the waking hours there is no dribbling of urine whatever. But it is not always easy to determine in a particular instance what share to attribute to the abnormal depth of the sleep and what to the diminished peripheral irritability of the bladder and its neck. There certainly occur cases in which the deep sleep from which some people can with difficulty be waked by calling, shaking, &c., is the only cause of the troublesome disorder in question. In other patients there seems to be a loss of peripheral irritability of the bladder. Further, it may be that an increased irritability of the nerve centres of the bladder in the lumbar region of the cord is the agency at fault, and that these, under the influence of an afferent stimulus less powerful than usual, straightway by an irresistible impulse determine the evacuation of the urine. Finally, for those cases in which there exists incontinence more or less marked, so that the child wets its clothes during the day and cannot in school time leave so quickly as to avoid doing so, we must assume some weakness of the sphincter of the bladder. We must, then, admit different causes in different cases; the seat of the mischief may be sought at very different situations in the channels of nervous influence that presides over the emptying of the bladder, below in the lumbar region of the cord, higher up in the dorsal region, and perhaps even in the brain. Since all the other phenomena of an organic lesion are constantly absent, we have to assume the existence of a functional disorder limited to these channels, and often in all likelihood depending upon a permanent neuropathic condition.

Treatment has reference chiefly and most frequently to the bladder itself, and the method suggested by Seeligmüller is to be preferred here by reason of its great simplicity and its efficiency, which is not less remarkable. Seeligmüller passes a rod of brass (or a metallic wire), about one centimetre in length, through the orifice of the urethra (in females as well as males), connects it with the kathode of a secondary faradic current, and applies the anode with a sponge electrode to the symphysis. A current is induced of some minutes' duration and appreciable intensity. The result is usually an immediate improvement, of which Seeligmüller adduces very striking instances, and amongst others the following :—

171. *Obs. of Seeligmüller. Enuresis nocturna* (*and diurna*).—A girl of 22 years of age had suffered from earliest infancy from incontinence of urine, which persisted night and day. Every possible remedy had been tried without success. There were frequent intervals of remission, lasting one or more months, in which the nocturnal enuresis disappeared entirely, but during the day the patient still suffered the greatest embarrassment from her disorder. During the last six months she has been regularly roused from a deep sleep two or three times during the night, and still it was not uncommon for her to pass water unconsciously. The effects of the disorder upon her general condition were very distressing. It was a bar to work and pleasure of every kind. Emaciation, cachectic appearance and depression. Treatment by faradisation, as detailed above, lasting five minutes. After the first sitting immediate improvement. In the daytime evacuation occurred twice only—the previous day every quarter of an hour; in the night not at all; sleep excellent. After the third sitting the condition was already quite normal. The patient, as usually happens, now sleeps lightly, and wakes at the least noise; whereas formerly she slept very soundly. After the eighth sitting she was discharged entirely cured. The cure has lasted; general health excellent.

For my part it is my custom to proceed as follows: I apply the anode to the lumbar cord; the kathode, which is smaller, first to the symphysis, then to the perineum; and I induce a pretty strong current, lasting 1 or 2 minutes. Finally I introduce into the urethra an electrode of metallic wire of about 2 centimetres' length. In girls I replace this by a small sponge electrode, which I pass within the labia, so as to bring it in contact with the orifice of the urethra. And here, too, I apply a faradic current of 1 or 2 minutes' duration, and of such intensity as to cause marked sensation and slight pain.

In the most obstinate cases I also pass a urethral electrode as far as the neck of the bladder, where I proceed to induce a current as described above. In every instance I combine with this galvanisation of the lumbar cord, and later of the entire cord as far as the cervical region, just as in the more serious forms of paralysis of the bladder. You will hardly ever have to resort to a direct application to the neck of the bladder by way of the rectum and urethra, as it has been practised by Erdmann, Duchenne, and Desparquets.

The results of this treatment by electricity are usually remarkable, especially when applied to children who are not very young. After one or a few sittings an improvement occurs—generally, after a little time, a complete cure. Still it sometimes happens that prolonged treatment is necessary, and I cannot deny that electricity has completely failed me in many cases, in spite of a well-considered application of all its resources.

Disorders of the Male Organs of Generation.

Of these it is especially functional disorders which call for the use of electricity. Of the others I have little to say.

The experiences furnished by Chéron and Moreau Wolf of successes obtained by them in the treatment by galvanism of *inflammation, swelling, and hypertrophy of the prostate* do not encourage great hopes, nor have they been confirmed since by those writers or any others. They introduce a metallic electrode by the rectum, and apply it to the prostate. It is usually the kathode, the anode only when there is manifest sensitiveness. The other is applied to the perineum. The strength of the current is moderate; it is continued for five to ten minutes, and the sittings in all are eighteen to twenty. The results are represented as marvellous, and the proceeding extolled as far more efficient than the other medical and surgical remedies. The authors mentioned pretend to have obtained equally good results in *blennorrhagic and traumatic orchitis.* They say that by means of galvanism they notably shorten the course of the disease, and render their patients fit for work. Their plan is to pass a strong galvanic current continuously through the swelling for 6 or 8 minutes, then a continuous current, proceeding from the most painful part of the swelling to the spermatic cord (4 or 6 minutes), and finally a current ascending in the course of the cord. Immediately following upon this application improvement sets in, and after a few sittings the cure is complete. These statements require confirmation. I have thought it my duty to quote them in order to direct to them the attention of those who wish in like manner to try the efficacy of electricity in this direction, the more so inasmuch as our knowledge of the katalytic action of the current forbids us to deny the possibility of such results.

In like manner electric currents have often been used, and with success, for the treatment of onanism and the sexual excesses that involve atrophy and degeneration of the testicles. The method is to pass faradic or galvanic currents of moderate strength through the substance of the testicles for a period of some minutes, and finally to galvanise at the same time the spermatic cord, on account of the vessels and nerves in connection with it.

The most important and promising field for electrotherapeutics, however, is the *functional disorders* that are so common, occurring in the various degrees of *impotence, morbid emissions, spermatorrhœa, and aspermatism.* I have not had the opportunity of studying in detail the pathology of these affections, so various, complicated, and important; and the less that the mode of procedure in applying electricity is nearly always much the same for all of them. I would refer you, then, for a fuller account to the admirable work of Curschmann and the chapter devoted to them in Benedikt's book. I must content myself here by reminding you that some of the disorders mentioned should be referred to anatomical peculiarities, or the results of inflammation of the urethra, the testicles and their connections, the spermatic cord, and prostate, and also to tumours, &c. Treatment by electricity, as a rule, is here of little use, and will rarely seem to be called for.

Still there is another class of cases that should be referred to serious organic disease of the nervous system, central or peripheral. In these the disorders of the genital functions, emissions, impotence, spermatorrhœa, priapism, &c., are but the symptoms of a possible incipient tabes, a chronic myelitis, or compression of the cord, or perhaps a more serious lesion of the nerves in the *cauda equina*, &c. It is known that certain affections of the spinal cord lead, at an early period of their course, to the impairment or even destruction of the sexual functions—so especially do tabes, transverse myelitis, compression, and chronic meningitis—while these functions may remain intact in others, as in the different forms of poliomyelitis, spastic spinal paralysis, &c. For the first treatment by electricity will yield good results by its direct action upon the symptomatic disorder of the genital functions, obviating their impairment when the primary disease has been removed. The possibility of cure, however, or even of improvement, will always be influenced by the original disease, and depend upon it. And, as Benedikt has very judiciously remarked, besides it is not always an unqualified advantage to the patient to have these functions too early re-established. In fact in a man suffering from tabes the excitement and irritation of the spinal cord, rendered thus possible again, may very easily become hurtful in the event of repeated intercourse.

A third group includes those cases of functional disorders of the genital organs in which they exist independently, proceeding from local causes, and ordinarily arising from over-use, and consequently the most complained of and oftenest submitted to treatment; or, on the other hand, those in which they are but a symptom of the functional impairment of the nervous system throughout, neurasthenia, spinal irritation, hypochondriasis, &c. Finally, these disorders may depend upon a neuropathic diathesis, a general weakness and irritability of the nervous system following, it may be, upon causes and antecedents of far less importance—as venereal excesses, inflammation, conditions of irritation and debility of the urethral canal in the neighbourhood of the ejaculatory ducts. These are by far the most frequent forms, and those too in which treatment has yielded its most splendid results, and for which electricity is in an especial manner indicated. It is for the most part the various degrees of *irritable weakness* of the genital tissues which concern us here, and which lead by a chain of various consequences to the impairment of virility, premature emission, defective erection, too frequent nocturnal emissions, and finally to pollution by day and spermatorrhœa; conditions which in their turn are very often accompanied by quite a series of different morbid nervous symptoms, neurasthenic phenomena in every quarter, and especially by a marked disposition to hypochondria.

But apart from these there are some cases which cannot be grouped with any of these three classes, in which, for instance, morbid emissions or aspermatism occur in men who are otherwise in good health, of blameless life, and wanting every sign of disease of the genital organs or nervous system. Finally, certain disorders are met with arising in the course of diabetes, lead poisoning, alcoholism, and other maladies. All these different conditions have been submitted with success, more or less marked, to the treatment by electricity, at the hands of various observers. The results quoted by Schultz, Benedikt, Möbius, &c., and to which I could add quite a catalogue of successes, proved beyond doubt that we must accord a great importance in this connection to the electric current, and that we may obtain the most satisfactory results in the great majority of cases by the use of electricity, either alone or in conjunction with other remedies.

The mode of treatment adopted here should of course have for its object the primary affection, and for many cases it is even the main end. I would refer you on this head to what I have said in their proper places concerning the treatment of cerebral disease and affections of the spinal column, and especially in connection with neurasthenia and the conditions associated with it. In so far as these come within the province of electrotherapeutics it behoves us to adopt the modes of application which circumstances require.

But in general you will not content yourself with this, for in many, perhaps in most cases, you will have to apply the electrical treatment *directly* to the organs of generation, just as it is usual to do when these affections present other symptoms. And further, this direct treatment will, on more than one occasion, be your chief concern, or even that which shall alone claim your attention in cases where the sexual disorder is the only or the most evident symptom of the general morbid condition.

In the great majority of cases we are called upon to stimulate and restore the nerve functions in question, so as to remove the paretic condition of the lumbar cord and genital nerves, and it is much less common to have to encounter conditions of irritability or over-excitement. According as we have to deal with one or other of these states, it is necessary to introduce into our treatment certain modifications which are suggested by general principles. Since the course and distribution of the genital nerves, in so far as they influence erection and the emission of semen, their connection with certain centres in the lumbar region of the cord, the relation of these centres, as of the genital centres themselves, with segments of the central nervous system in its higher parts (even in the brain to the seat of the sexual instinct, the imagination, &c.) offer the closest analogy with the conditions of innervation of the bladder, it follows necessarily that the methods of electrical treatment for functional disorders of the genital organs are, on the whole, the same as those used in affections of the bladder. This is no less the outcome of a consideration of the methods employed by the different observers.

To this end, as a rule, the galvanic current is to be preferred. The plan which I regard as the most suitable is as follows: The anode—a large electrode—upon the lumbar region of the cord; the kathode, of medium size, being applied in a stabile and labile manner along the spermatic cord from the hinder part of the groin, for 1 or 2 minutes. The current must be pretty strong, causing a decided smarting in the skin (30° to 40° deviation of the needle). Then the kathode, stabile, is applied to the dorsal and ventral surfaces of the penis as far as the glans, and vigorous currents are passed for about 1 minute. Again, with the kathode labile and stabile upon the perineum above the scrotum at the root of the penis, for 1 or 2 minutes. To this may be added occasional interruption and reversal of the current, so as to cause more energetic stimulation. If there is present some anæsthesia of the penis, especially of the glans, you can subject it somewhat longer to the action of the kathode. If the testicles are atrophied and flaccid, and the scrotum cold, make the current pass directly through their substance. This is the procedure which must be adopted, especially for the cure of impotence. If the patient suffers from morbid emissions or spermatorrhœa it is advisable to relinquish the more irritating measures, and to employ principally constant currents, and, if necessary, with the anode to the perineum. If you have reason to suppose that the spermatorrhœa depends upon a lax or irritable condition in the neighbourhood of the ejaculatory ducts, or is maintained by such a condition, it will suggest the direct application to these parts by means of the urethral electrode. This should be introduced as far as the prostatic part of the canal, and in case of irritability a kathodic current is passed through, in one of debility the anodic ; always of gentle strength and extremely short duration, for fear of wounding the parts.

Faradic treatment, however, for impotence and spermatorrhœa, is by no means necessarily to be excluded. To carry it out you apply the electrodes almost in the same situations and for the same period. In general tolerably strong currents are employed. Direct faradisation of the testicles, too, is called for in cases of deficient nutrition and flaccidity of these organs. Gunther claims to have practised it successfully in azoospermia. If there is anæsthesia of the skin—and by means of the farado-cutaneous examination we can often determine a diminished sensibility—or notable coldness of the penis, flaccidity of the scrotum, &c., the faradic brush may be applied with advantage to the genital organs, and in like manner to the perineum and the neighbourhood of the anus, from which we can obtain a considerable reflex contraction of the scrotum. The faradic current may also be applied through the urethra, but here you must guard against a too violent stimulation. The application of one electrode through the rectum has been suggested by Möbius, so as to bear more closely upon the ejaculatory ducts and prostate. Möbius places the other electrode upon the perineum and makes use of 'fluctuating' faradic currents of 2 or 3 minutes' duration ; and in addition a brief galvanisation with the kathode in the rectum and the anode on the sacrum. He extols the results of this proceeding. For my part I have never resorted to it.

In every serious and obstinate case I never fail to employ a system of regular galvanisation of the lumbar cord, in which are situated the most important centres of sexual function. In cases of probable anatomical deficiency I add to this galvanisation of the cauda equina in its lower part, and usually extend it to the cervical region of the cord, especially in patients in whom a loss of tone in the genital nervous system generally seems likely to obtain.

The treatment should always be continued for a considerable time. It should last at least for 6 or 8 weeks, often much longer, and daily sittings should be given. In most instances other forms of treatment should be adopted at the same time, as the exhibition of tonics, baths, the water cure, &c.

The results which I have obtained in this way were often very satisfactory, especially in cases of purely functional disease. At the same time I have been baffled by cases which afforded a favourable prognosis, and which yet entirely resisted the treatment by electricity. It is therefore well to withhold too great hopes at the outset, except of course in those instances where we have to deal with a kind of physical impotence, and in which we administer electricity to the patients rather with a moral object than that of combating some physical affection.

There have been published in different quarters independent observations and even large works (and lately in particular an excellent work by Dixon Mann) upon the DISEASES OF THE FEMALE ORGANS OF GENERATION and their treatment by electricity, and yet, amongst us in Germany at all events, they do not seem to have engaged the attention of gynæcologists, or if so, it has escaped my notice. For my part I have, so to speak, no personal experience upon this subject, and consequently I have no mature opinions concerning it. Nevertheless the notices which have been published elsewhere are so worthy of attention that they might well have claimed a little of the consideration of gynæcologists, with whom it rested to apply to their own branch of science the powerful resources of electricity, closely connected as it is with nervous pathology. A consideration which should greatly influence them is that the uterus is a muscular organ, highly vascular and richly supplied with nerves. And yet there evidently remains here an extensive and fruitful field for the action, vasomotor and katalytic, stimulating and sedative, of the electric current. It is true that efforts in this direction, so great in extent and results when viewed from the standpoint of science, can be conducted only by specialists in gynæcology.

Here, then, I must confine myself to a brief allusion to the most important notices which have been published on the subject. I leave them for careful examination in the hands of other observers.

With reference to that affection of the ovary characterised by extreme sensitiveness to pressure, so common in nervous and hysterical women, and which bears the most intimate relation to many nervous derangements, I have already made some observations (Lecture XXVII.) It would certainly repay the trouble to pursue further the hints which I have given there as to the effect of electrical treatment.

On the treatment by electricity of the various disorders of menstruation there are published many notices (Rockwell, Baker, Althaus, Taylor, Fieber, Good, Dixon Mann).

For the cure of *amenorrhœa* persisting at puberty or developed later from a variety of causes—debility, the nervous diathesis, anæmia, &c.—the electric current often proves very efficient and striking in its results. Those who use it have often had occasion to observe that the menses flowed with extraordinary abundance and even prematurely under treatment, especially when the back and thighs were galvanised, or a general faradisation resorted to, a result which seems to afford the prospect of an effectual cure in electricity. Moreover, the ascertained powerful influence of the electric currents upon the vessels and vasomotor nerves when the uterine muscles are stimulated would lead us on *a priori* grounds to hope to exercise a beneficial control over the processes of menstruation.

Should you desire to treat such a case of amenorrhœa, you might adopt for the purpose the following course: With the faradic current pass the brush over the soles of the feet or inner surface of the thighs, or faradise from the nape of the neck to the region of the uterus, a proceeding which Althaus began by saying was alone effective. Later, however, he adopted the galvanic current instead. Dixon Mann, in addition to the use of galvanism, directly faradises the parts from the kidneys to the cervix of the uterus, at the period of expected menstruation.

Most observers, however, have preferred *galvanism.* Here you may apply *galvanism to the sympathetic in the neck* (Fieber, Good), or *galvanism to the vertebral column*, especially its lower segments (Clemens, Good), *galvanism to the lumbar region* (anode) with the negative pole at the ovaries (Good, Althaus), or finally *intra-uterine galvanisation* (Dixon Mann, Althaus), when, like Dixon Mann, you may introduce the kathode within the uterus and apply the anode over the lumbar cord or ovaries, or with Althaus place the anode at the os uteri and apply the kathode alternately to either ovary. For a uterine electrode you may employ an instrument resembling a catheter or a small sponge-electrode, or a small electrode fashioned like a plate for application to the cervix. It will be necessary to make use of a tolerably strong current (from 7 to 9 millimetres according to Dixon Mann) for 10 to 15 minutes two or three times a week. The results will often be astonishing.

I have already intimated that electricity will yield good results in connection with *dysmenorrhœa*. I would remind you of Neftel's statements with reference to cases of this kind which he pronounced to be of the nature of visceral neuralgia. In such cases, then, of painful spasmodic menstruation, you can first make trial of Neftel's method (anode to dorsal and lumbar cord, kathode on the hypogastrium, ovaries, &c.), and if necessary you can fall back upon the following plans: that of Schwanda, the application of galvanism and faradism to the uterus; Taylor's, the use of feeble, uninterrupted galvanic currents, with the A on the sacrum and the K in the form of a small metallic rod of appropriate size placed within the os uteri. In preference employ the method of Dixon Mann, the anode (a uterine electrode) within the uterus, the kathode over the lumbar cord, and an uninterrupted current, lasting 10 minutes; the treatment to be repeated three times a week in the intervals between the menstrual epochs. The results are said to be excellent.

There are *a priori* reasons to expect that in certain circumstances electricity might be used with advantage for the cure of *menorrhagia*, and in a broader sense for metrorrhagia, especially in view of the active influence of the current in exciting uterine contractions. In point of fact, favourable results have been published by different authors. Thus Mackintosh saw a severe hæmorrhage occurring after child-birth instantly arrested in consequence of uterine contractions induced by the application of the faradic current to the cervix uteri and abdomen. Further, Dixon Mann has treated and obviated the disease in question by galvanising the uterus (with the kathode in the uterus and the anode over the kidneys) for 15 minutes twice a week, with a pretty strong current in the interval *between successive periods of menstruation.*

Of derangements of the uterus itself, *chronic metritis* has in an especial degree been made the object of electrical treatment. Here it is from the katalytic and vasomotor effects of the current that we should expect the most favourable effects. Beau and Tripier make use for this purpose of the faradic current. The former places a moistened sponge electrode against the os uteri, and the other upon the abdomen. Tripier inserts one of the electrodes within the uterus, and the other, which is in two parts, at once on the rectum and over the anterior wall of the abdomen; or else in the case of young girls he faradises superficially from the abdomen to the sacrum. On the other hand, Bartholow has effected his purpose by means of the galvanic current. He placed the anode with the aid of a speculum at the os uteri, the kathode on the hypogastrium, using the current uninterruptedly for five or ten minutes two or three times a week. Dixon Mann places the kathode in the uterus and the anode over the lumbar region, a pretty strong current interrupted occasionally in the last resort. Attempts have also been made with electricity to correct *displacement of the uterus.* And this proceeding has some advantages in those cases where the displacement is really due to an enfeebled condition of the uterine walls, and in which we may hope to remedy it by causing contractions and restoring the muscular tone. But in many other cases there are hardly any grounds to hope for success. The methods to be adopted for this purpose may vary much. Simpson long ago recommended a form of intra-uterine pessary for displacements as well as for chronic metritis, and since that time many observers have obtained favourable results from the treatment by electricity, both in inversions and flexions of the uterus. While Bartholow made use only of the galvanic current in the way prescribed above, E. Mann has adopted alternately faradic and galvanic treatment. Still the greater number of physicians have restricted themselves to the faradic current (Beuvain, Fano, Elleaume, Zannini, Tripier, &c.), with the object of causing vigorous contractions of the uterus, and so obviating the displacement. In most instances they have merely passed the faradic current from the os uteri to the abdominal wall. Zannini introduces an electrode within the rectum, the other being placed in the uterus, and passes a faradic current of progressive intensity for a space of five or six seconds. Tripier has minutely detailed the methods adopted for this purpose. In anteversions and anteflexions he faradises the posterior wall of the uterus with a suitable electrode, passing the current from the rectum.

In analogous displacements backwards, on the other hand, he faradises the anterior aspect of the uterus, starting from the bladder or the abdomen; in either case one electrode (the negative) is placed within the uterus itself. In prolapse of the uterus he claims to have obtained good results from a bi-inguino-uterine or inguino-vaginal faradisation. At all events the published notices and their results call for further researches in connection with these conditions, which are certainly very obstinate to other treatment.

Finally, I will mention the expedients that have been adopted with the electric current to restore the failing *secretion of milk*. That this treatment has been successful in many instances is proved by the statements of Aubert, Becquerel, Lardeur, and Estachy. Various modes of procedure are open to us here too. Nearly all these physicians have applied the current directly to the chest, by means of moistened electrodes placed in different positions upon the mammary glands. They have employed currents of moderate strength, and after 2 or 3 sittings of ten or twenty minutes they have witnessed the restoration of the suspended secretion. Some have obtained this result by means of the friction apparatus, others with the faradic current. Quite recently, on the other hand, static electricity has been recommended as very efficient in this respect.

With reference to the application which has been made of electricity to obstetric practice, to excite labour pains, induce premature delivery, to obviate hæmorrhage before and after parturition, I shall pass this by, because it has not come within my own notice and is apart from the province of this book. Moreover, you can easily deduce from the general principles of electric treatment whatever considerations may possess practical value in this respect.

Before I bid you farewell, gentlemen, allow me to place before you some brief statements, which may be thought to possess practical interest, and which I have not yet had occasion to make. You have doubtless remarked with surprise that throughout the entire discussion of electrotherapeutics I have nowhere dwelt with much insistence upon the contra-indications to the use of electricity. But, possessed with the notion of contra-indication as it enters into ordinary therapeutics, you will agree with me that in the case of a remedy like electricity, which can be graduated so nicely and administered in such minute doses, one which can produce the most various and contradictory effects—which acts now as a stimulant and again as a sedative, at one time as a tonic, at another as an alterative—it can hardly be possible to establish very definite contraindications. In fact, after mature reflection on the subject I must admit that I am unable to lay down any such; but I am bound to acknowledge that these contraindications occur often enough in particular cases. And yet they have reference to one or other of its forms only, rarely to electricity in general.

Under this head the state of the circulation of the blood vessels seems to me to require special attention. We must remember that one of the most striking effects of electricity is the dilatation and increased flow of blood in the vessels submitted to its influence. In every case, then, where danger to the patient might arise from increased blood supply, pressure, or hyperæmia, the use of electricity, or at any rate of those forms which promote the circulation, appears to me to be contra-indicated. Hence the practical advice to withhold it in cases of acute inflammation. Further, it should be used guardedly in patients with degenerated or atheromatous vessels, miliary aneurisms, hypertrophy of the heart, &c., or, in plain terms, you are cautioned not to use electricity in the case of old people or apoplectics, whose vessels are diseased, and even though there exists no special evidence of this condition. It is, then, after all, the condition of the nervous system, its excitability in a greater or less degree, the manner and nature of its reaction with the electrical stimulus, that enables us to decide whether electricity will be useful or injurious. As regards the degree of susceptibility to electricity Beard, and more lately Möbius, have made some statements which it behoves us to consider. There are some people in whom the electric current is powerful for good or for evil, while others again are but little affected by it. It is especially in patients of a nervous, neurasthenic or hysterical temperament, that an extraordinary susceptibility to electricity is witnessed, so much so that very weak currents induce pain, and may lead to an aggravation of their distemper. It may even happen, rarely it is true, that this aggravation, as in the case of other remedies, is so marked as to lead us to assume in these patients an idiosyncrasy intolerant of electricity. This constitutes a contra-indication to its use; whilst a lesser degree of susceptibility entails but the necessity of great caution in choosing the strength of the current, and of proceeding by careful steps to more active treatment. It is not uncommon to see such persons become very tolerant of electricity when its use has been continued some time. In the majority of cases this susceptibility to its influence, so far as prognosis is concerned, is far from being of unfavourable import for the success of the treatment.

This is all that I have thought it necessary to say to you concerning the contra-indications to the use of electricity, and you will bear it in mind when you first enter upon practice.

I have finished my task, gentlemen; and I believe that I have placed before you a tolerably complete account of the present condition of electrotherapeutics in its bearings upon medical pathology. I am well aware that I have left many gaps unfilled, that I might have added many details, and that there is much that it would have been well to study and discuss with more minuteness, before it could be made the foundation of a practical system. I hope that these omissions will not have escaped your notice. I would have wished to submit the subject to you with clearness and accuracy, and to have shown you, as far as it was in my power, the course you should pursue in the various events that arise in practice. If I may hope that I have shown you the principles and scientific groundwork of a system that you will constantly have occasion to modify in practice, I must also admit that I have been constrained to expose at the same time the scantiness and insufficiency of our knowledge and the uncertainty of our power. I am glad that I have been able to enlist your interest in the efforts and researches of science which bear upon our subject, and to which I have ventured to call your attention in different parts of my lectures. It will be a new gratification to me if you, by your zeal and personal investigations, would take your part in the solution of these problems, and so contribute to the progress of electrotherapeutics in general. It is especially in the domain of therapeutics that there is still much, very much, to be done.

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